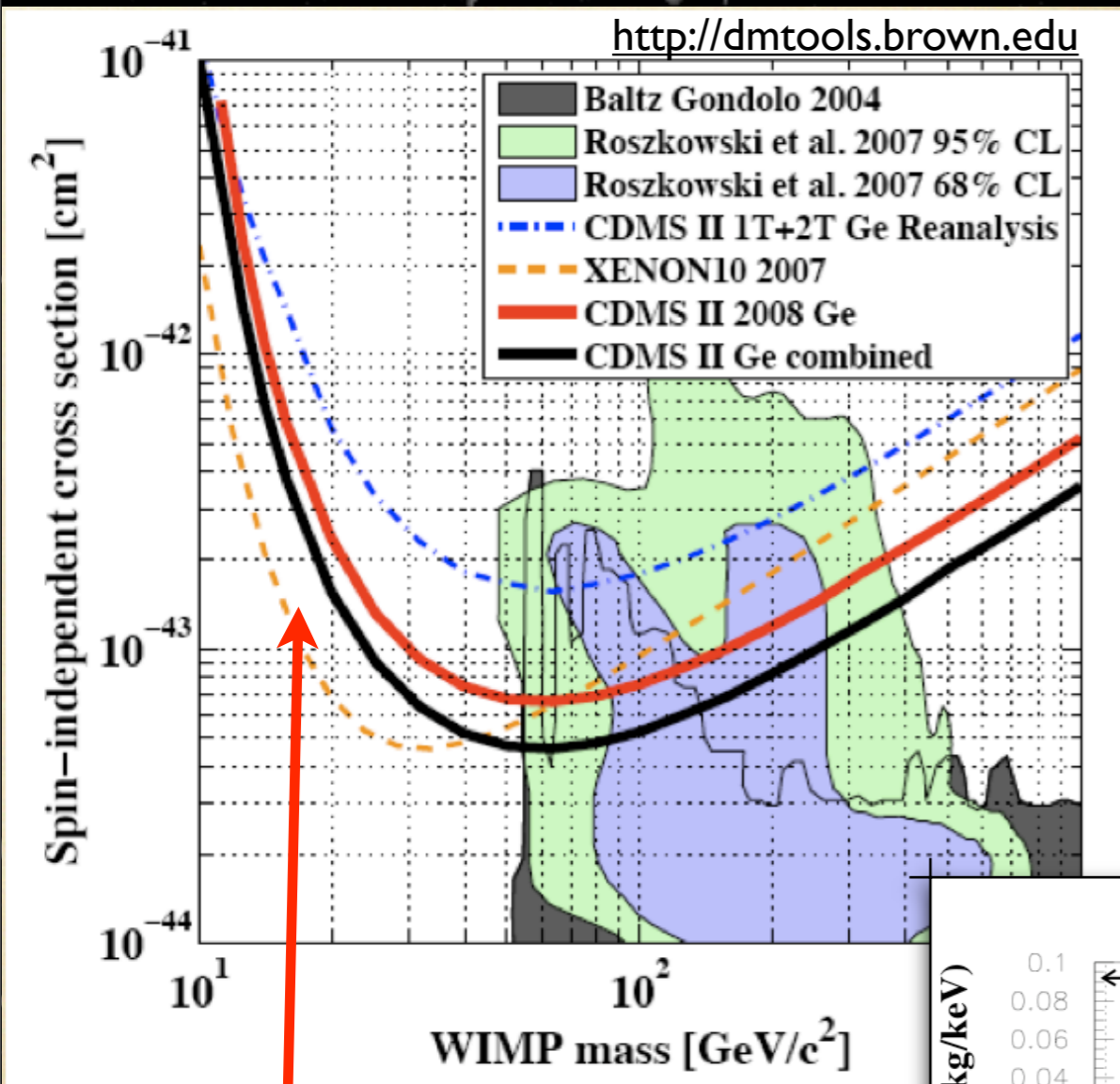


Low mass Dark Matter search with CCDs (DAMIC)

J. Estrada
8/31/2009

DM search results



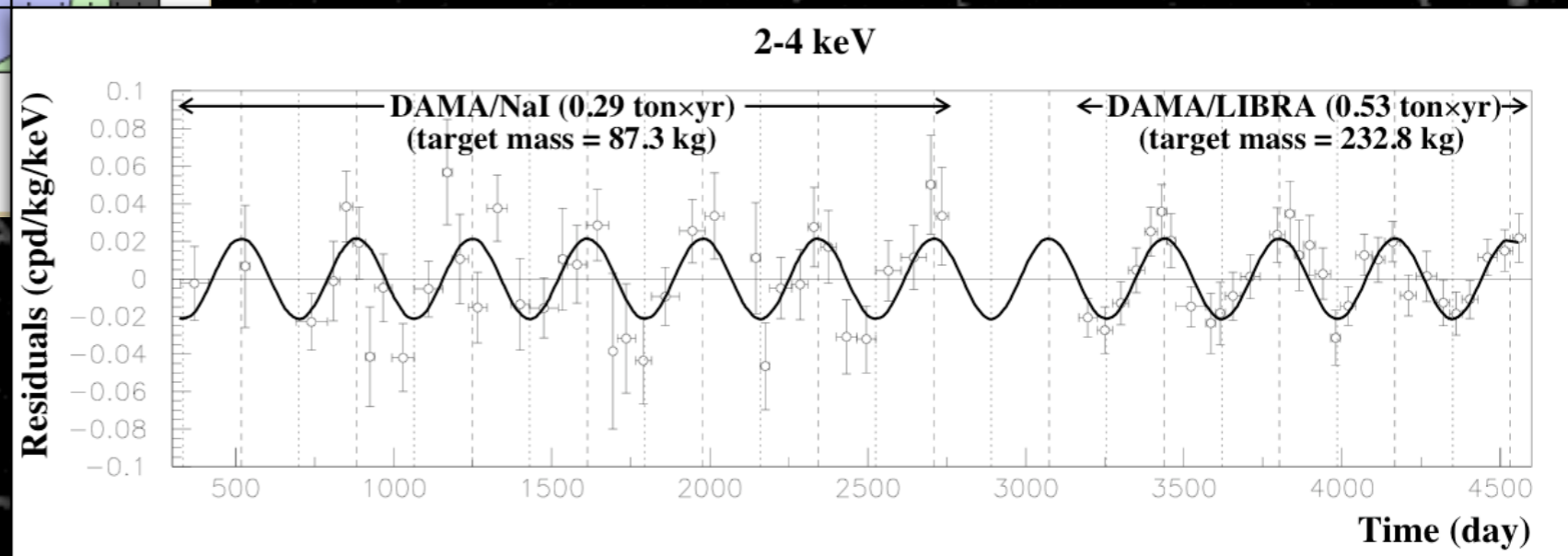
minimal SUSY likes heavy WIMPs, and most experiments are trying to cover that area.

Experiment	Target	Exposure (kg-d)	Threshold	Ref
CDMS-SUF	Ge	65.8	5 keV	[2]
	Si	6.58	5 keV	
CDMS-II	Ge	121.3	10 keV	[3]
	Si	12.1	7 keV	
XENON10	Xe	131	4.5 keV	[5]
CRESST-I	Al ₂ O ₃	1.51	0.6 keV	[16]

from Petriello & Zurek 0806.3989

I am proposing here to setup an experiment to look at the region below 10 GeV.

limited by detector threshold, typically a few keV. This limitation comes in part from the readout noise.



the recent DAMA/Libra result is a good motivation for this search, but there are other reasons too.

Focal detectors for DECam (the DES imager)

Science goal requires DES to reach redshift $z \sim 1$

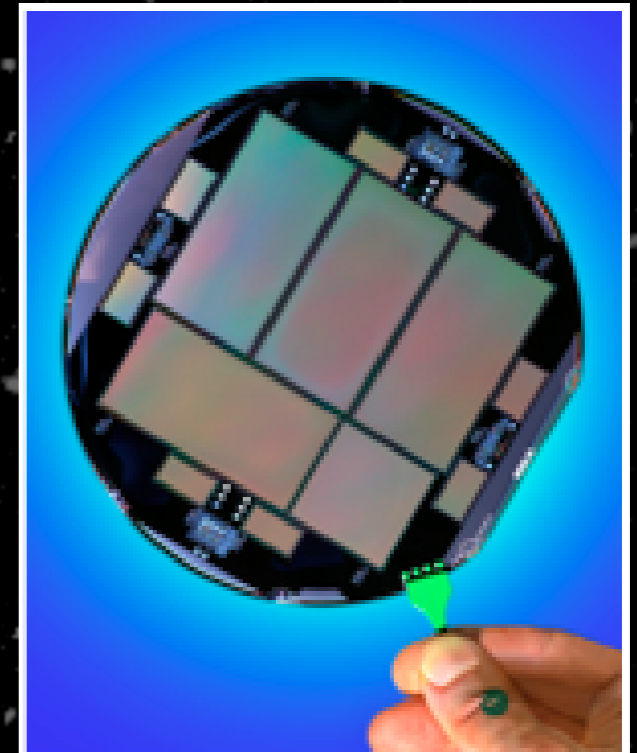
we want to spend $\sim 50\%$ of time in the filter (825-1100nm)

Astronomical CCDs are usually thinned to 30-40 microns (depletion) which makes them transparent to near IR.

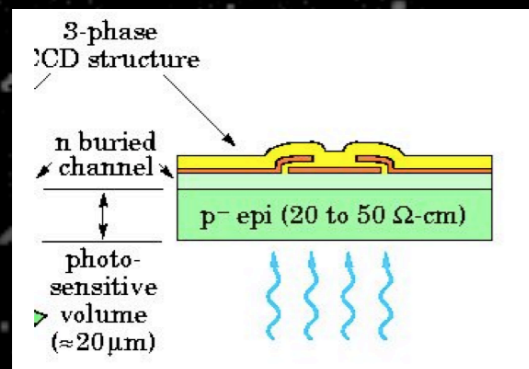
LBNL full depletion CCD are the choice for DECam:

- 250 microns thick
- high resistivity silicon
- QE > 50% at 1000 nm

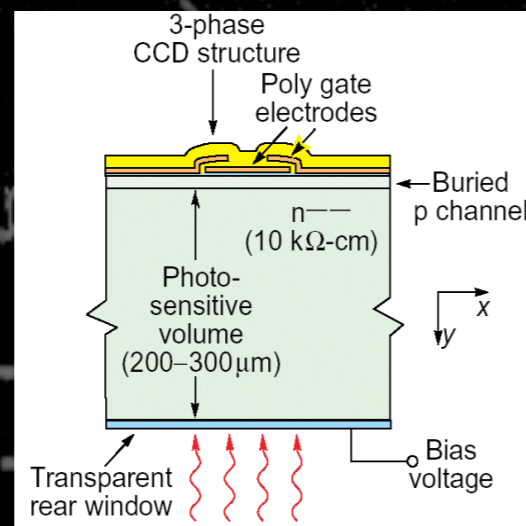
DECam wafer



typical CCDs

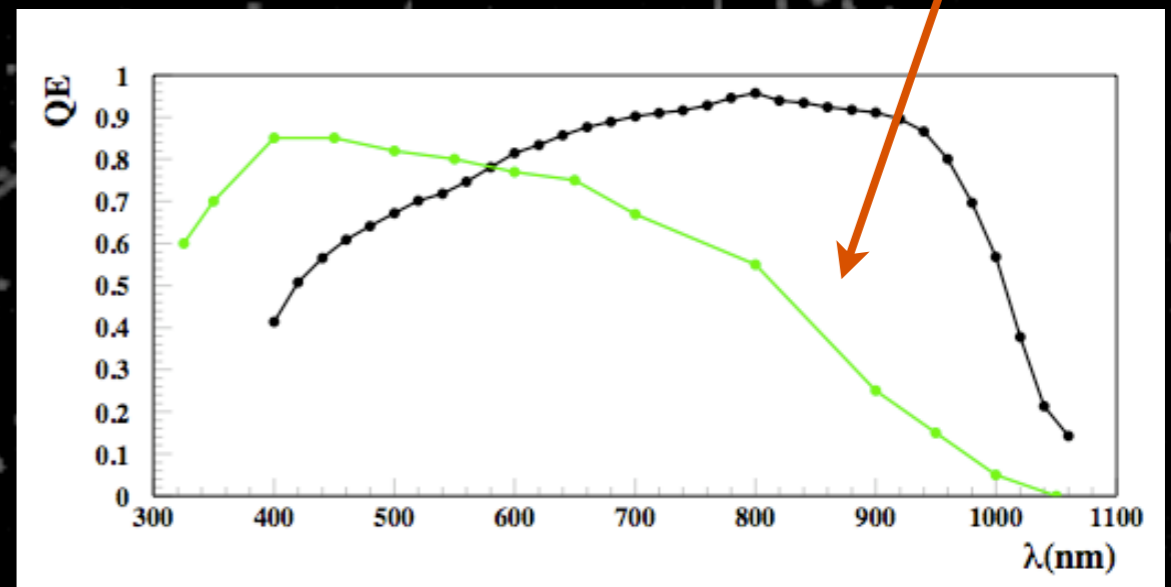


new thick CCDs

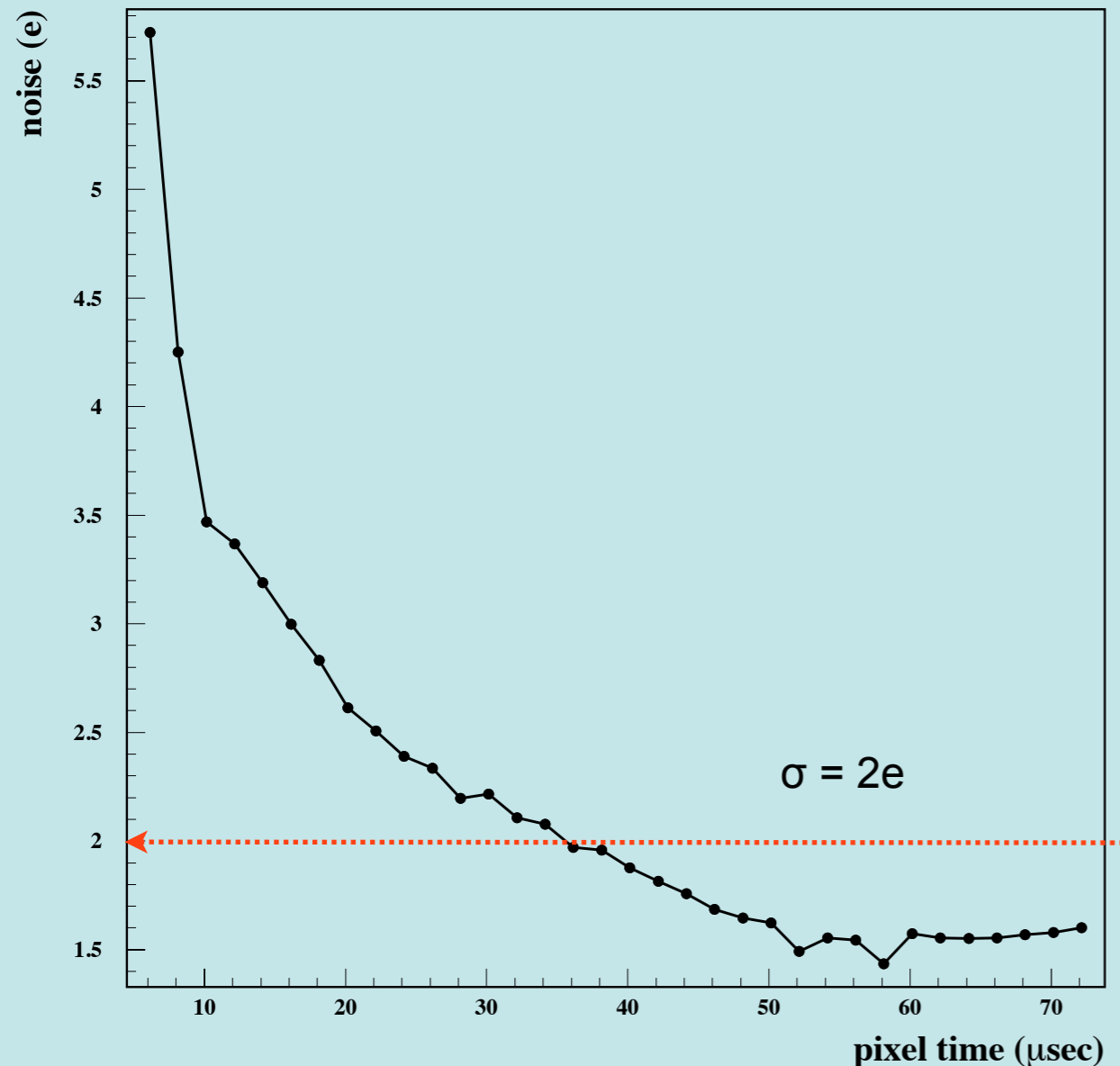


massive CCDs

higher efficiency for hi-z objects.



New opportunities with these CCDs



Two features:

CCDs are readout serially (2 outputs for 8 million pixels). When readout slow, these detectors have a noise below $2e^-$ (RMS). This means an **RMS noise of 7.2 eV in ionization energy!**

The devices are “massive”, 1 gram per CCD. Which means you could easily build ~10 g detector. DECam would be a 70 g detector.

Interesting for a low threshold DM search.

- 7.2 eV noise \Rightarrow low threshold (~ 0.036 keVee)
- 250 μm thick \Rightarrow reasonable mass (a few gram detector)



clear difference between tracks and diffusion limited hits.

nuclear recoils will produce diffusion limited hits

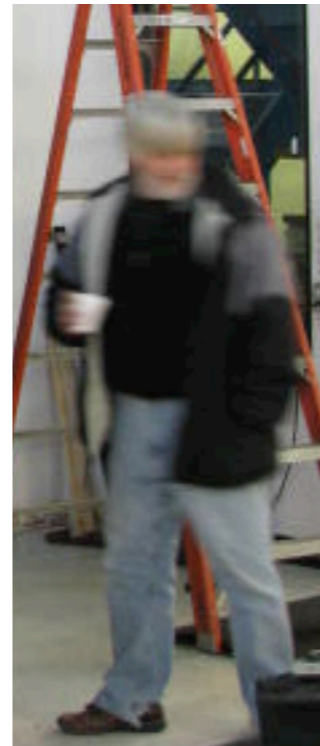
... thanks!



T. Nebel (inside)



J. Tweed



S. Jakubowski



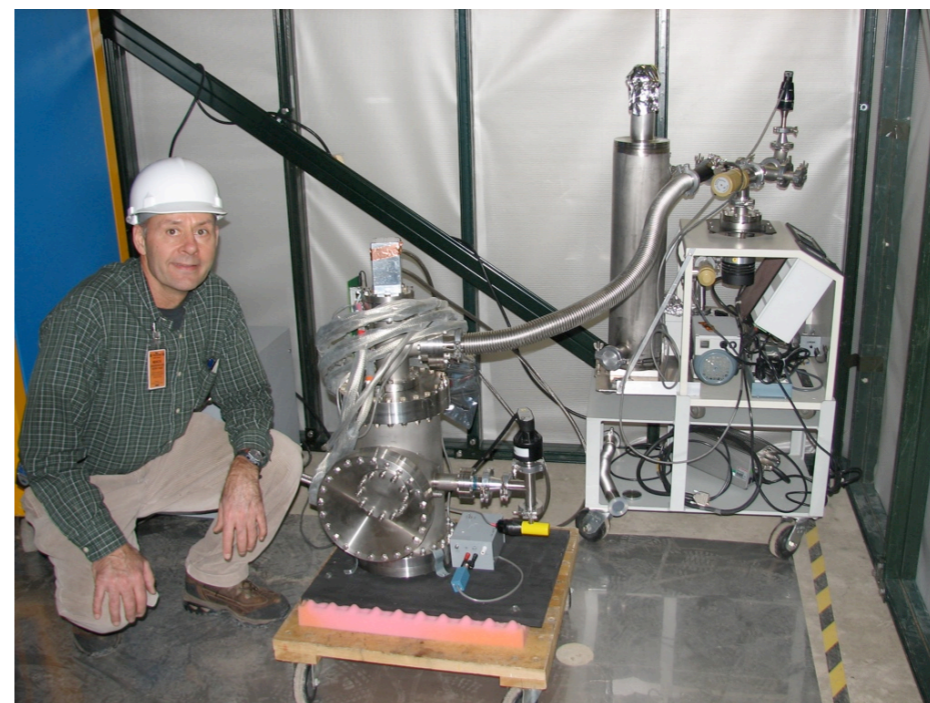
K. Schultz



J. Voirin



J. Delao (and lead workers)



K. Kuk



M. Watson

DAMIC (FNAL MOU T987) - 2009

Underground test of CCDs

CPA people:

DES: T. Diehl, J. Estrada, B. Flaugher, , D. Kubik, V. Scarpine

COUPP: E. Ramberg, A. Sonnenschein

CDF: Ben Kilminster

Visitors:

J. Molina (CIEMAT), J. Jones (Purdue)

Engineering (mostly DECam people and spares when available)

Mech: H. Cease, K. Schultz

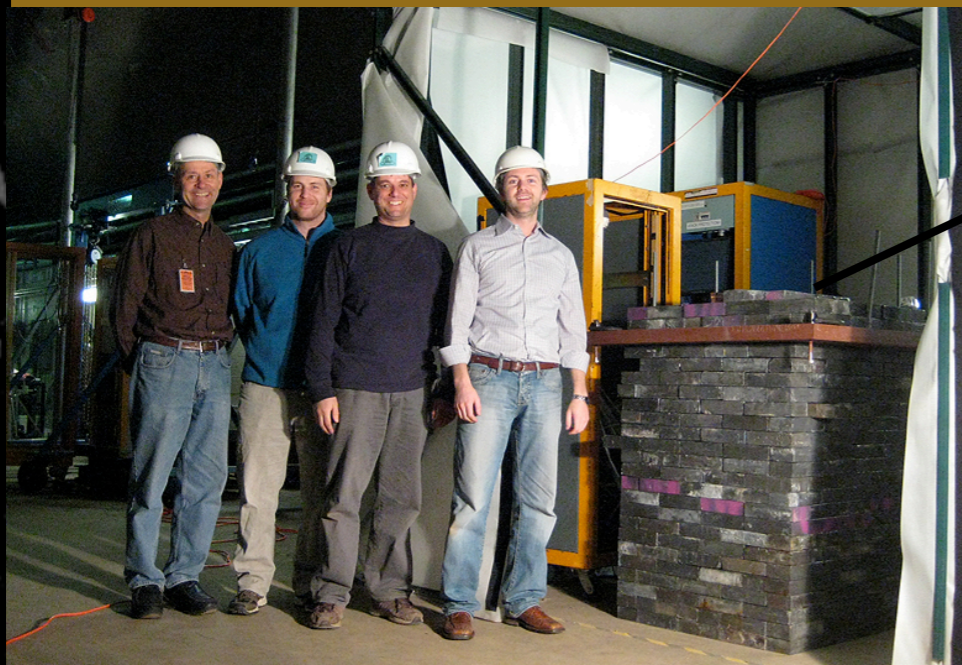
Electrical: T. Shaw, W. Stuermer, K. Kuk

Support:

> Detectors and electronics are DECam engineering parts

> PPD : shield + tent underground

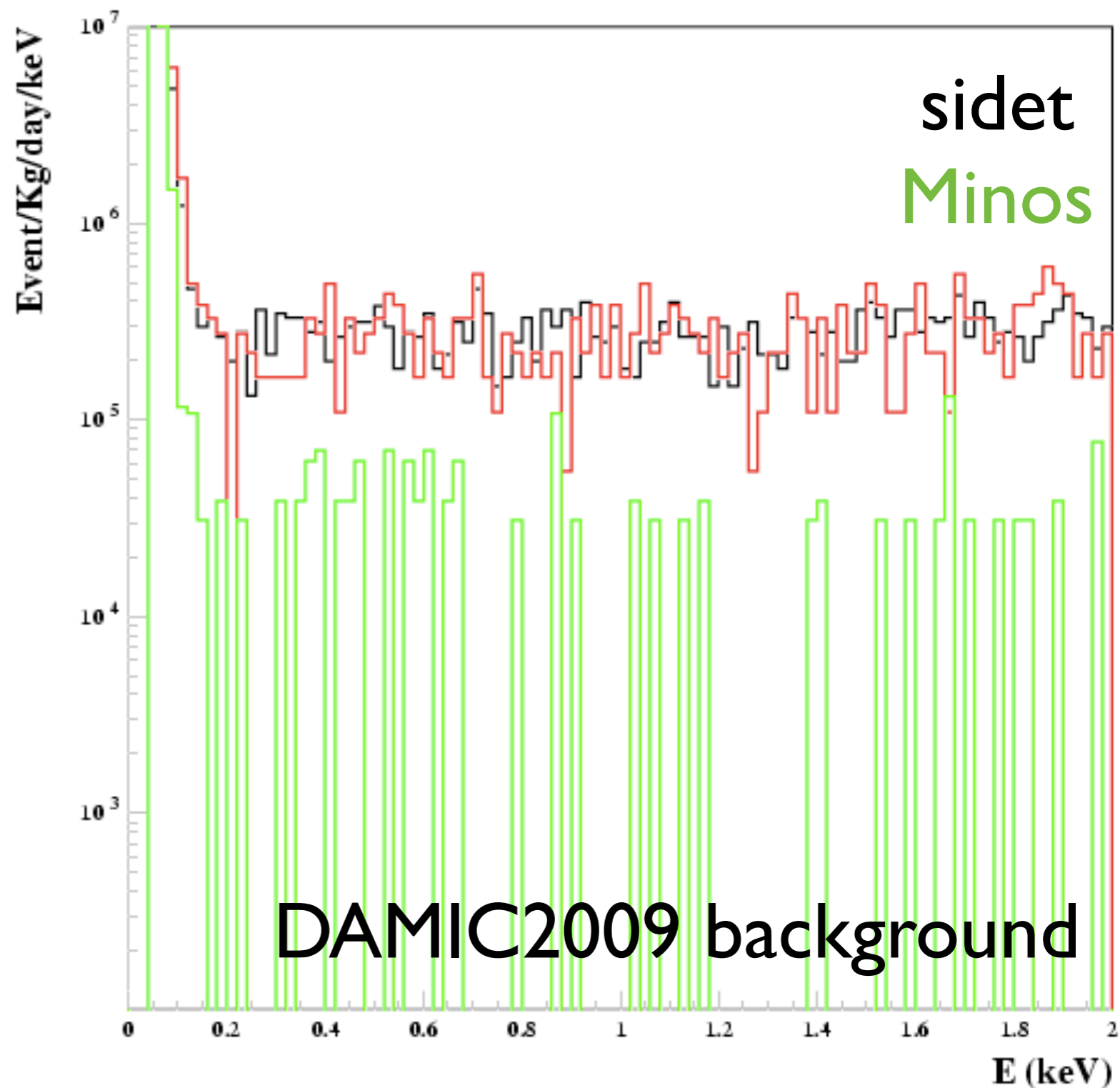
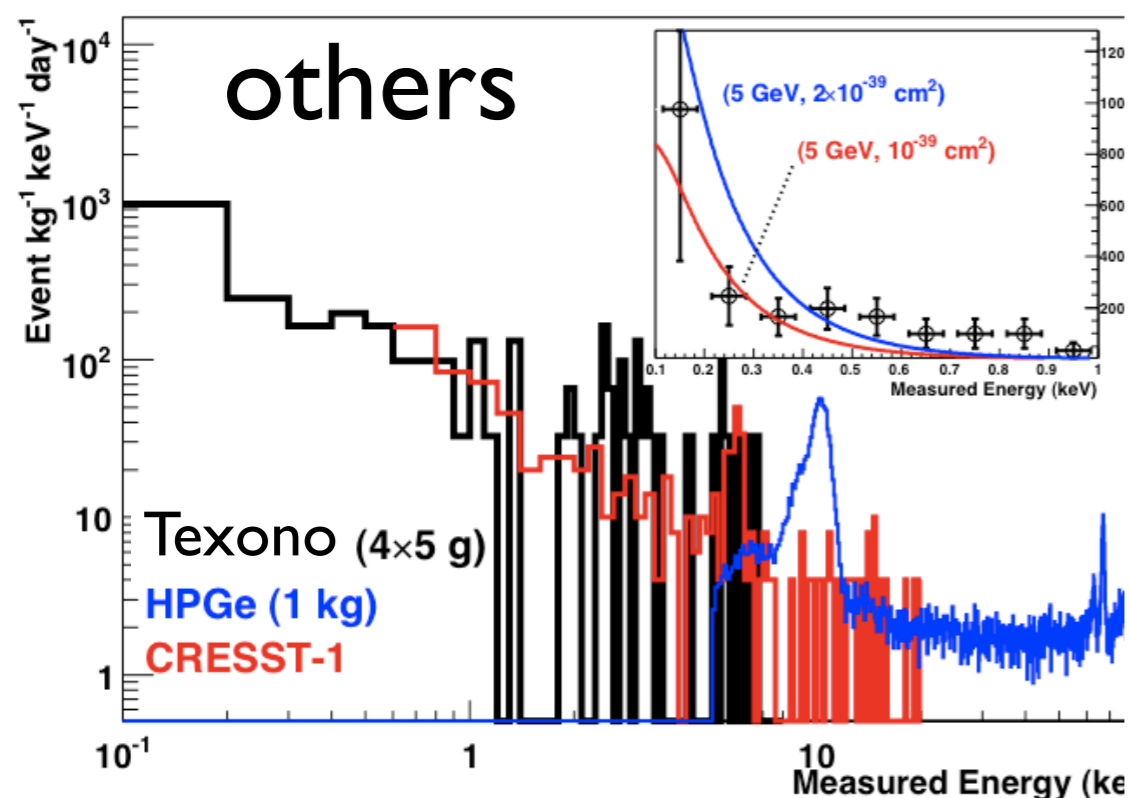
> CPA : some electronics boards (VIB)



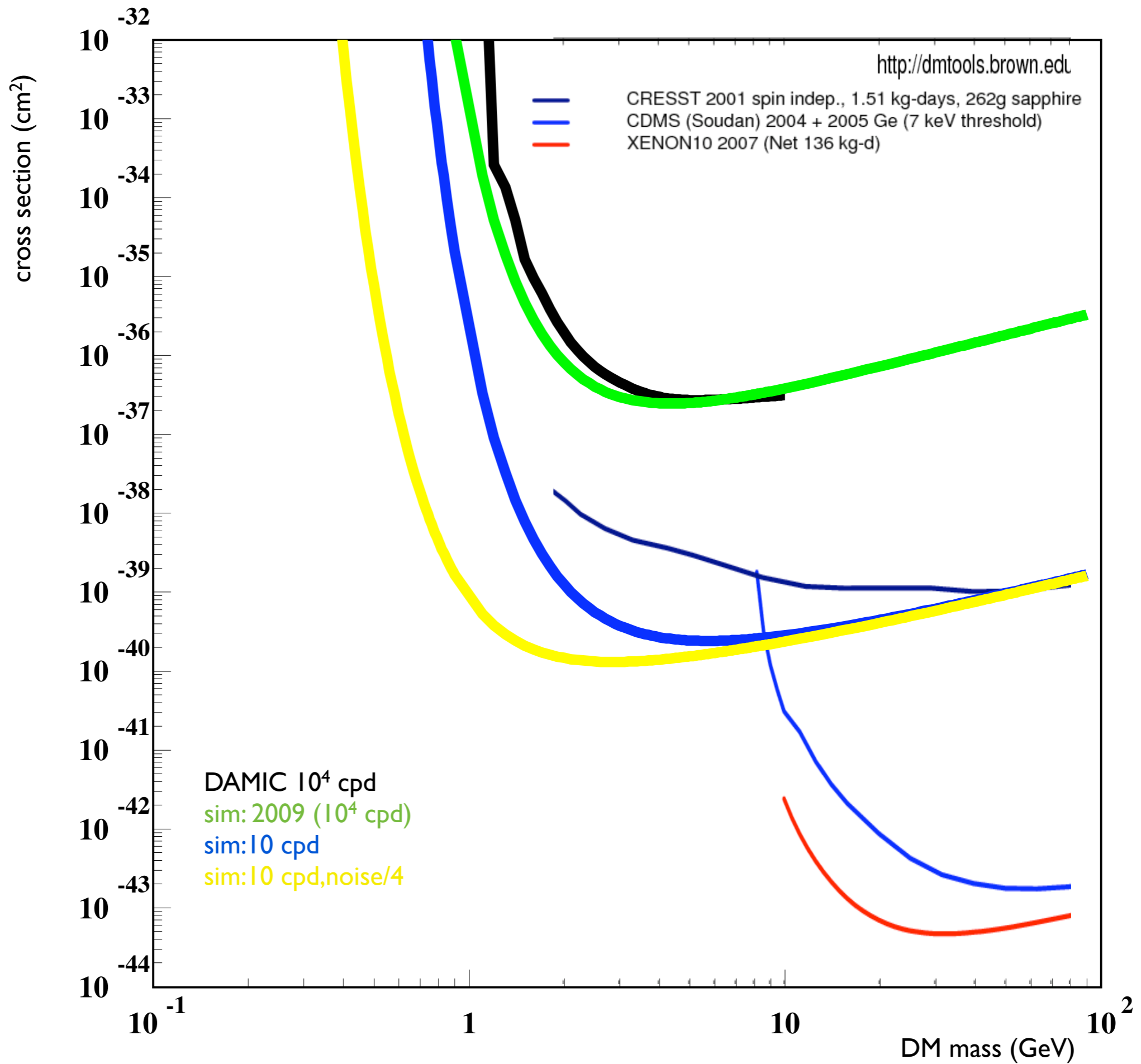
4CCD array here. ~350 foot depth

Our first test was not build with low background materials (just with FNAL surplus) + some lead.

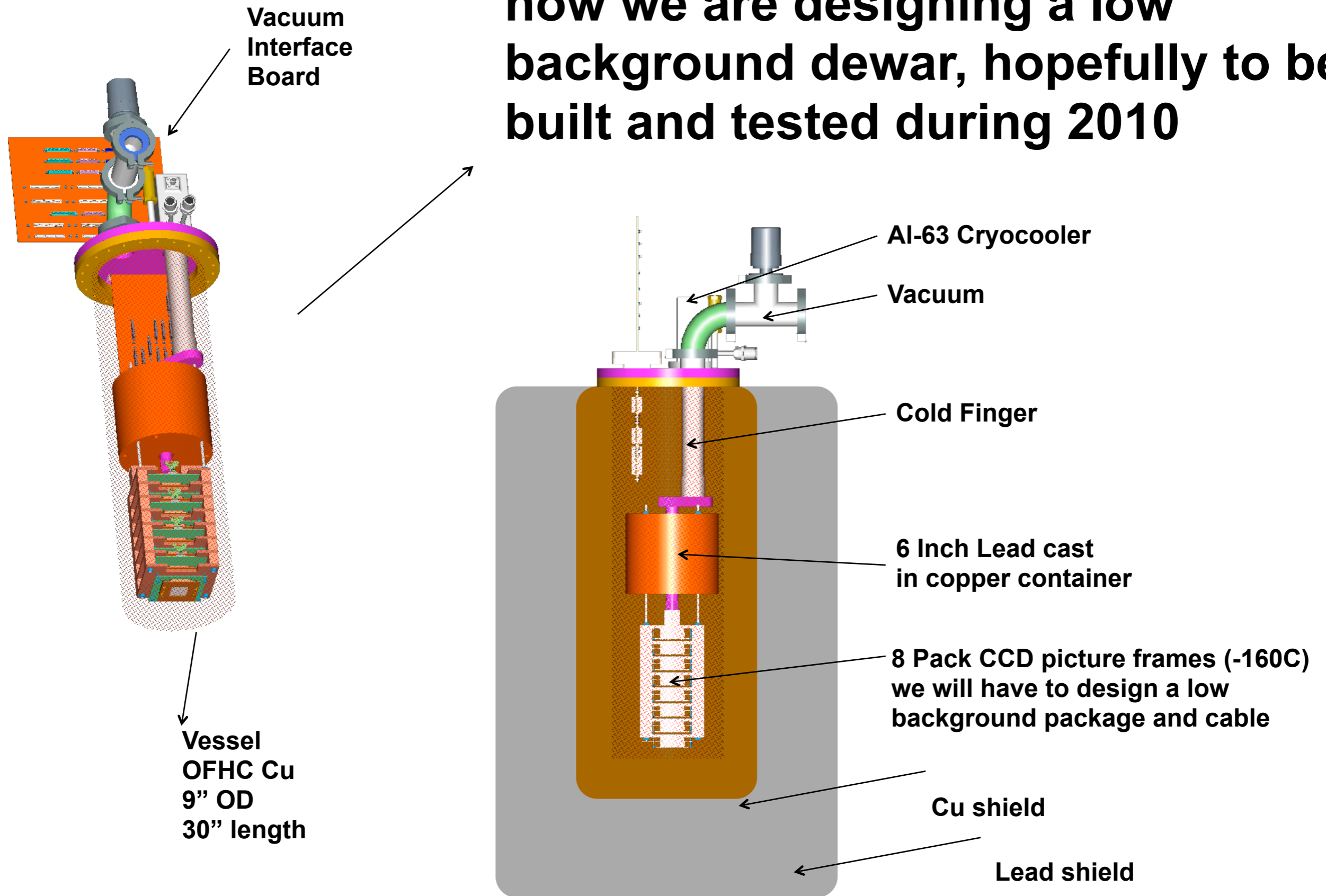
Big improvements over runs at SiDet, but x1000 larger background than others.



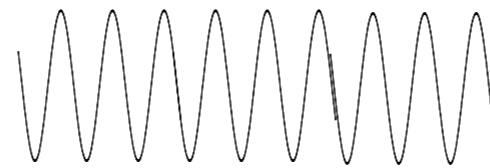
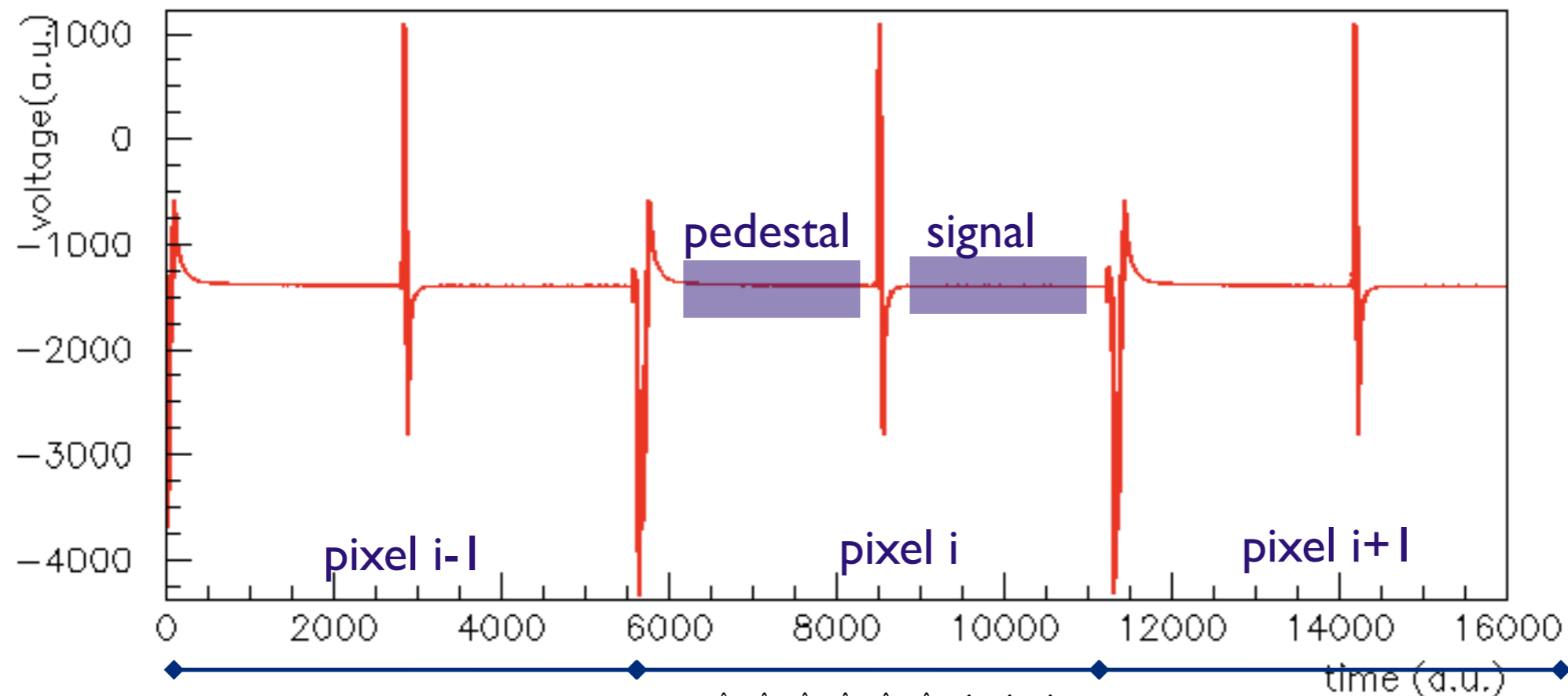
Right now our rate goes up at 0.06 keVee. For nuclear recoils this translates into (x0.14) ~0.5 keV. We believe that we can still push the threshold a bit lower with the same readout system (reduction 30%), and we are investigating a much lower threshold setting with a new readout system (DCR).



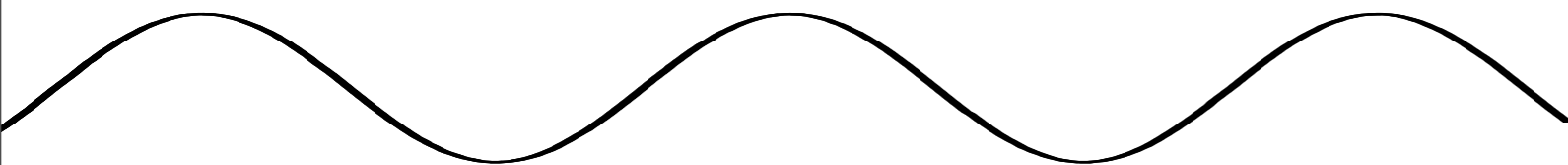
now we are designing a low background dewar, hopefully to be built and tested during 2010



Low noise R&D : Collaboration with C. Cancelo from CD



well filtered by integration in CDS

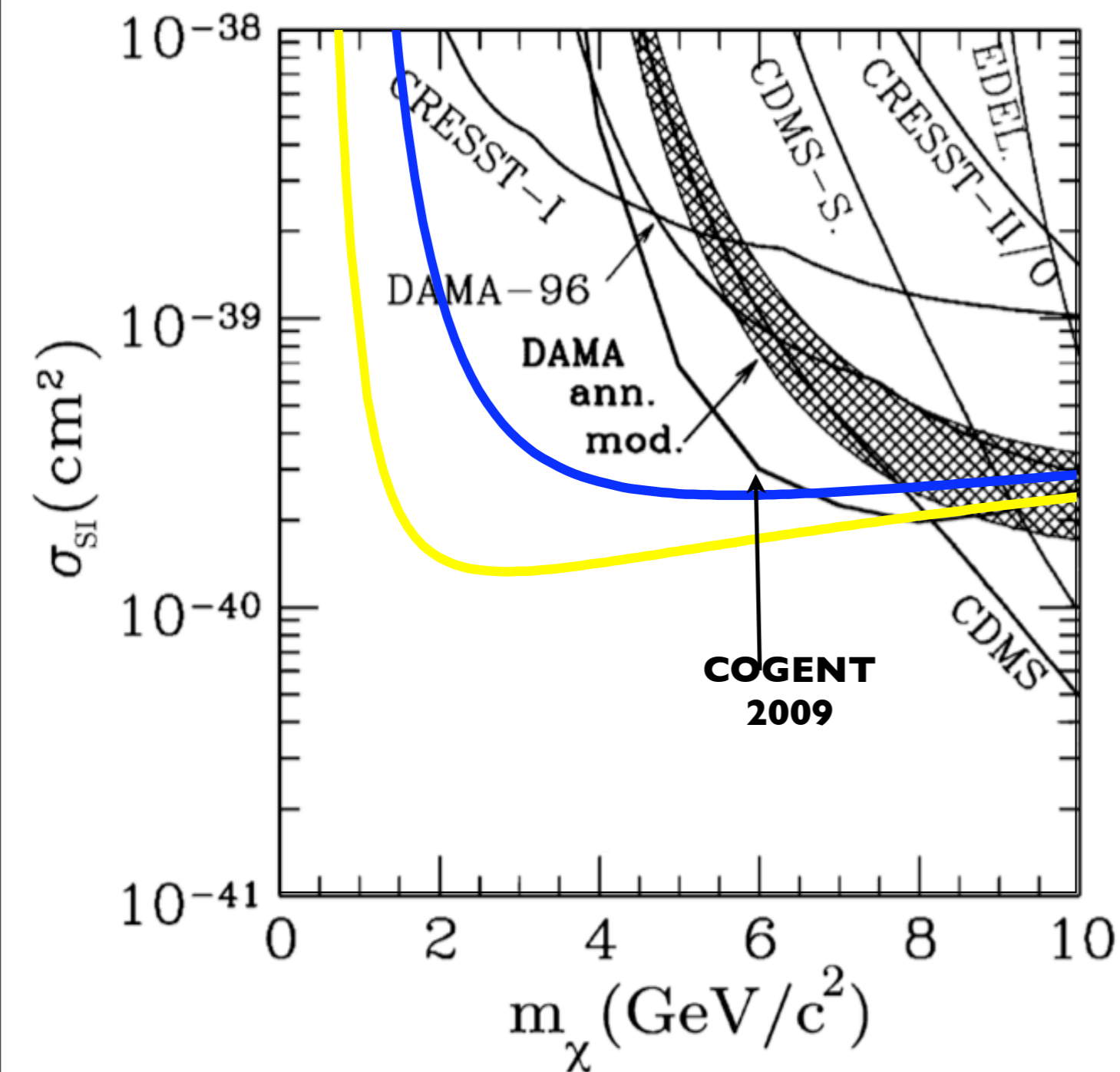


not filtered by the CDS

could be filtered by looking at many pixels

CDS: the amount of charge on each pixel is given by the difference between signal and pedestal levels inside an integration window. **High frequencies are suppressed by the integration window, low frequencies are suppressed by the double sampling.** working on digital filtering of the intermediate frequencies by looking at the signal over many pixels...

low threshold competition

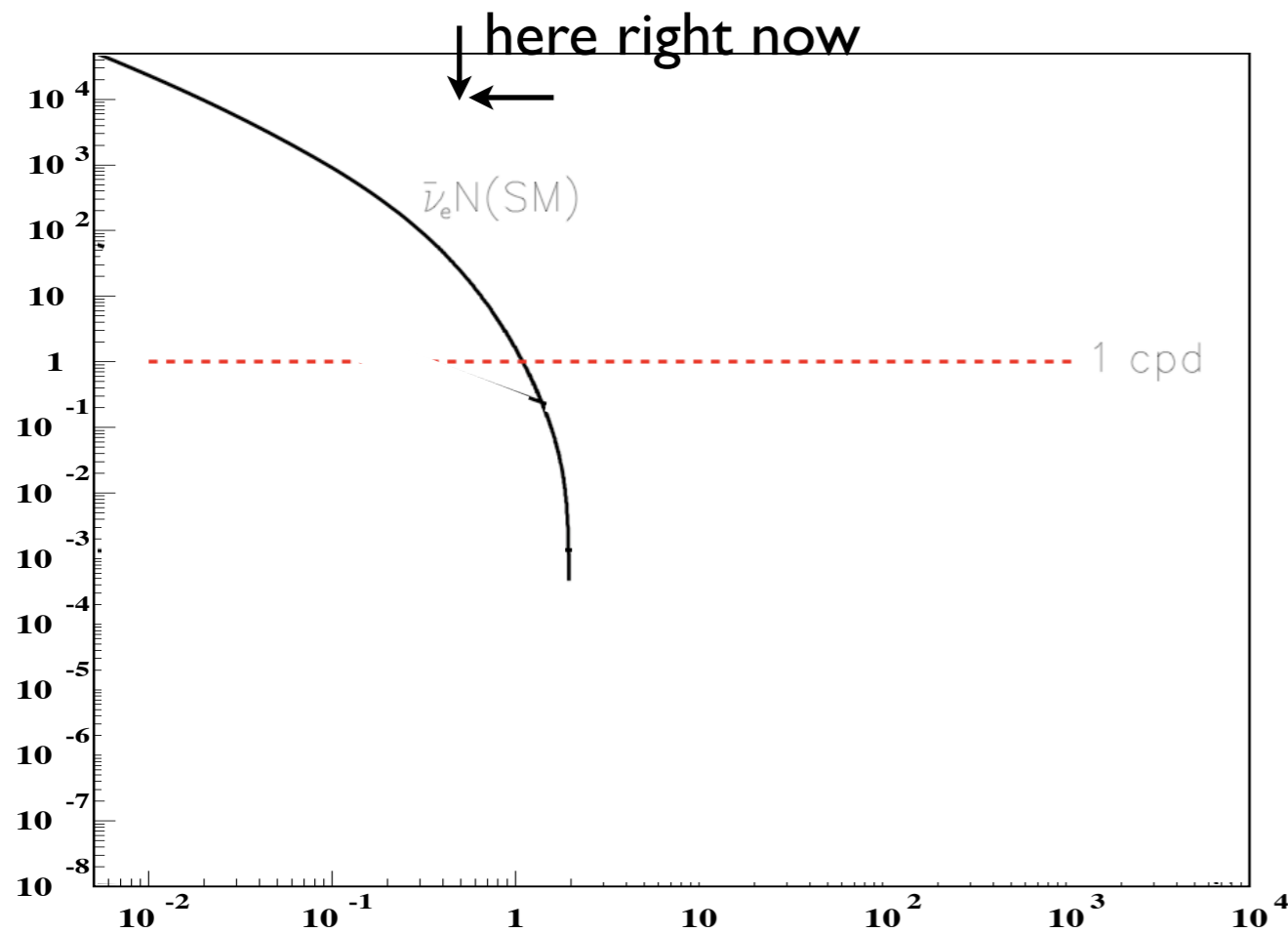


I think we can really get to the lower thresholds than anyone else, specially if the digital ccd readout succeeds.

CCDs are very easy to operate in a stable way, we have some operational advantages over others. We already have a detector running continuously at MINOS with little supervision since January.

CDMS is also pushing for a very low threshold.

possible applications outside DM



neutrino coherent scattering spectrum at 28m of a 3GW reactor (Texono Collaboration). This is a possible application of the low background low noise detector like what we are trying to build.

lowering noise



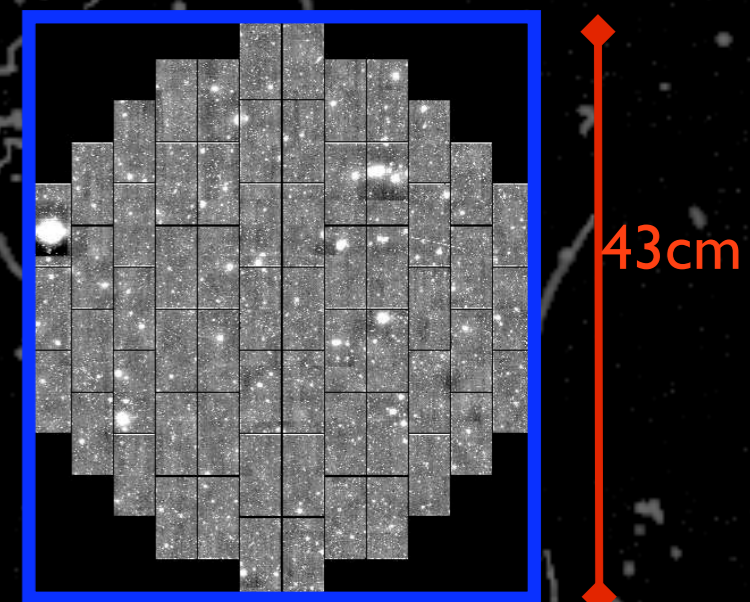
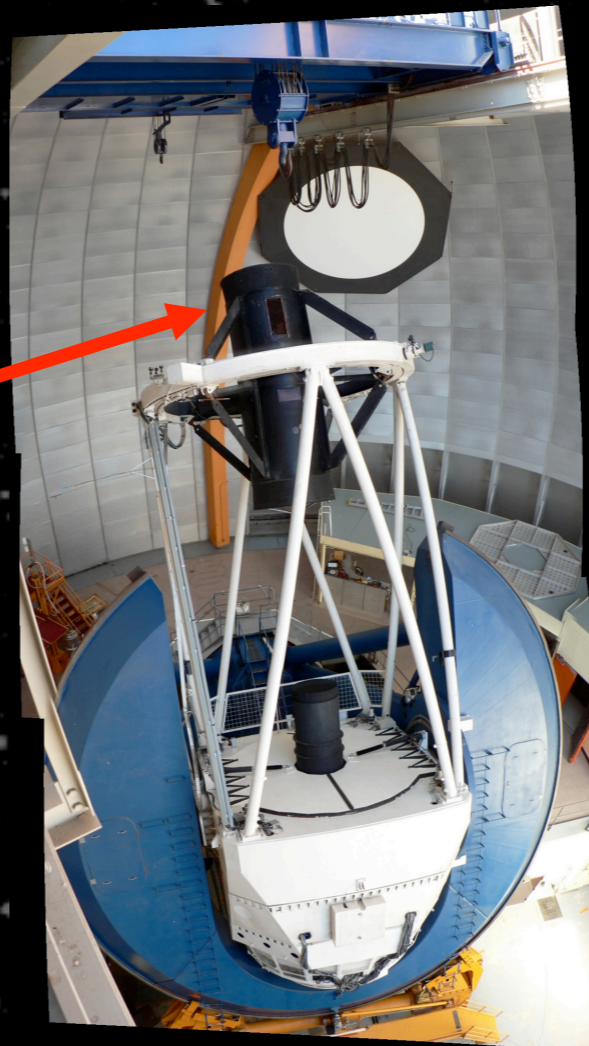
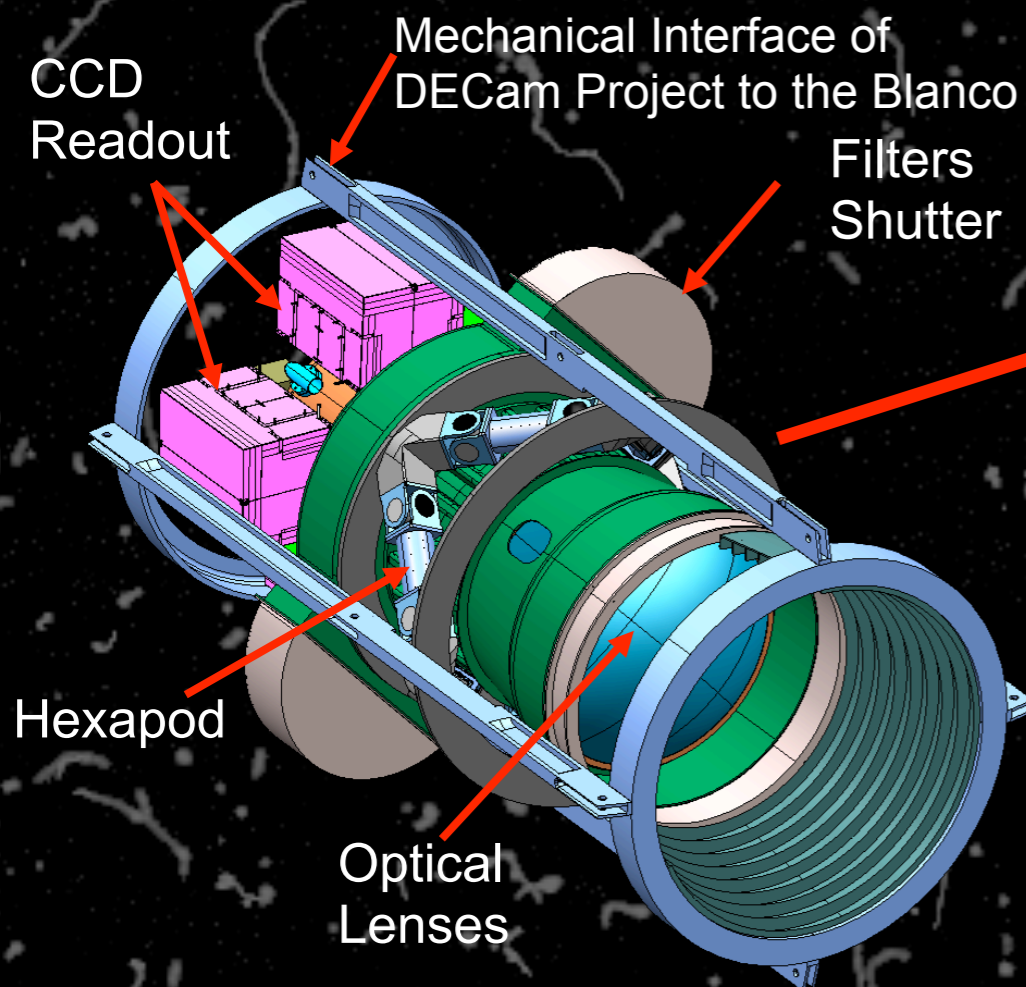
some astronomical observations have no background, and reducing the noise is equivalent to multiplying your telescope collecting area

Conclusions

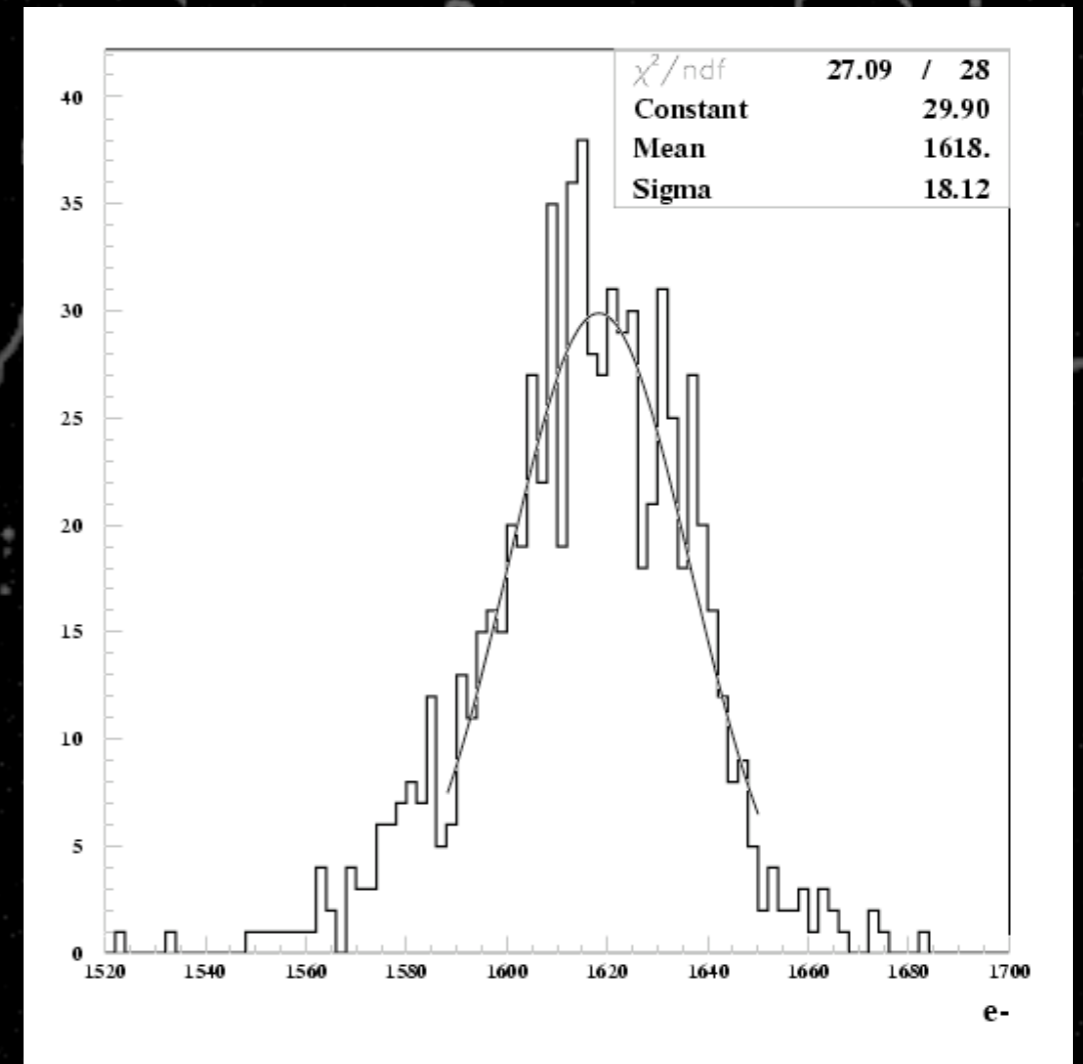
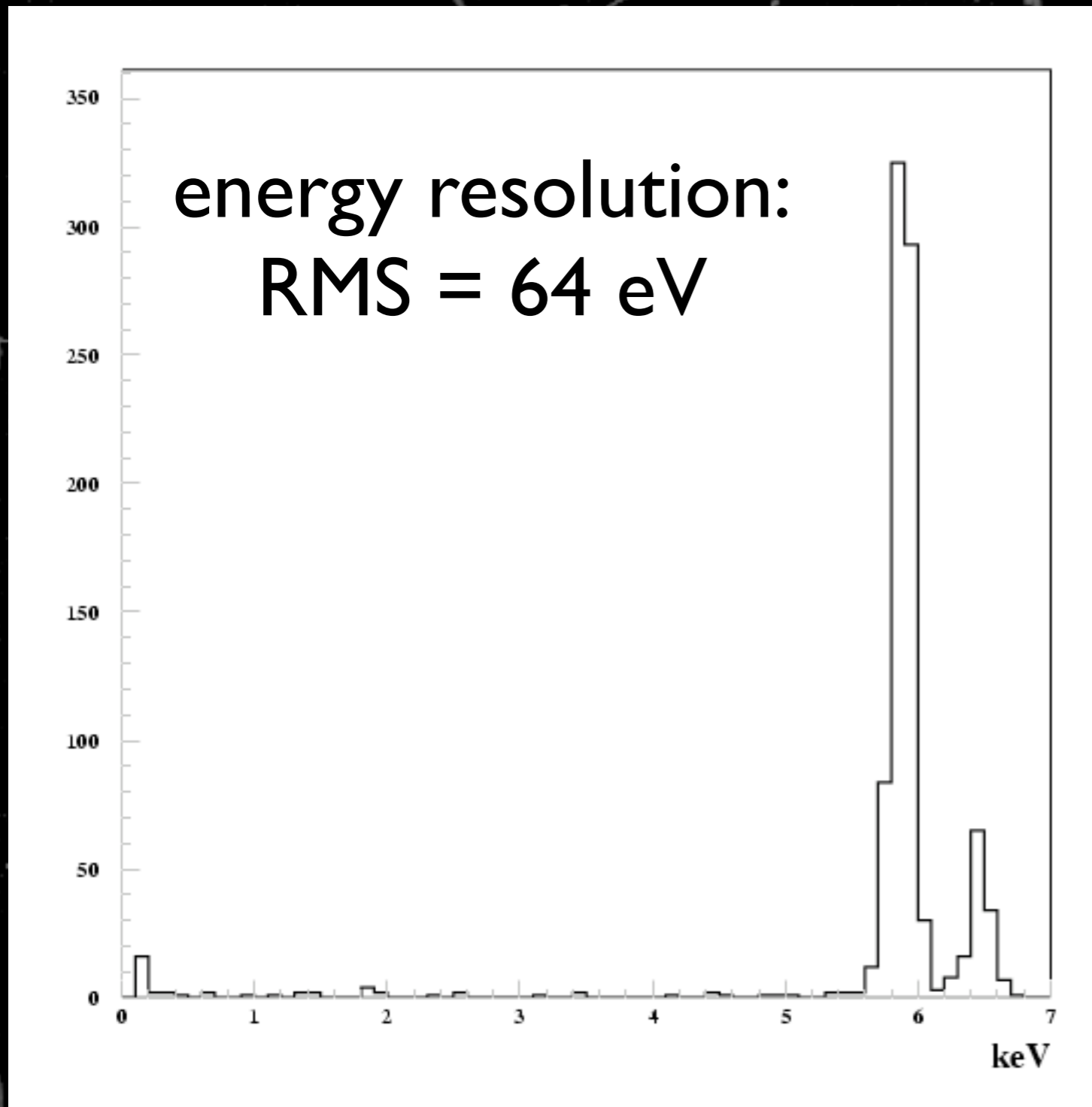
- R&D program for a low threshold direct dark matter search with CCDs. This search is well motivated by recent results and theoretical models.
- Need to develop a low noise and low threshold experiment with CCDs. We have large experience with these detectors and CPA has large experience with low background experiments.
- The technology developed in this effort could have applications outside dark matter searches: neutrino physics (coherent scattering) and low noise CCD readout (high resolution spectroscopy).

Dark Energy Camera (DECam)

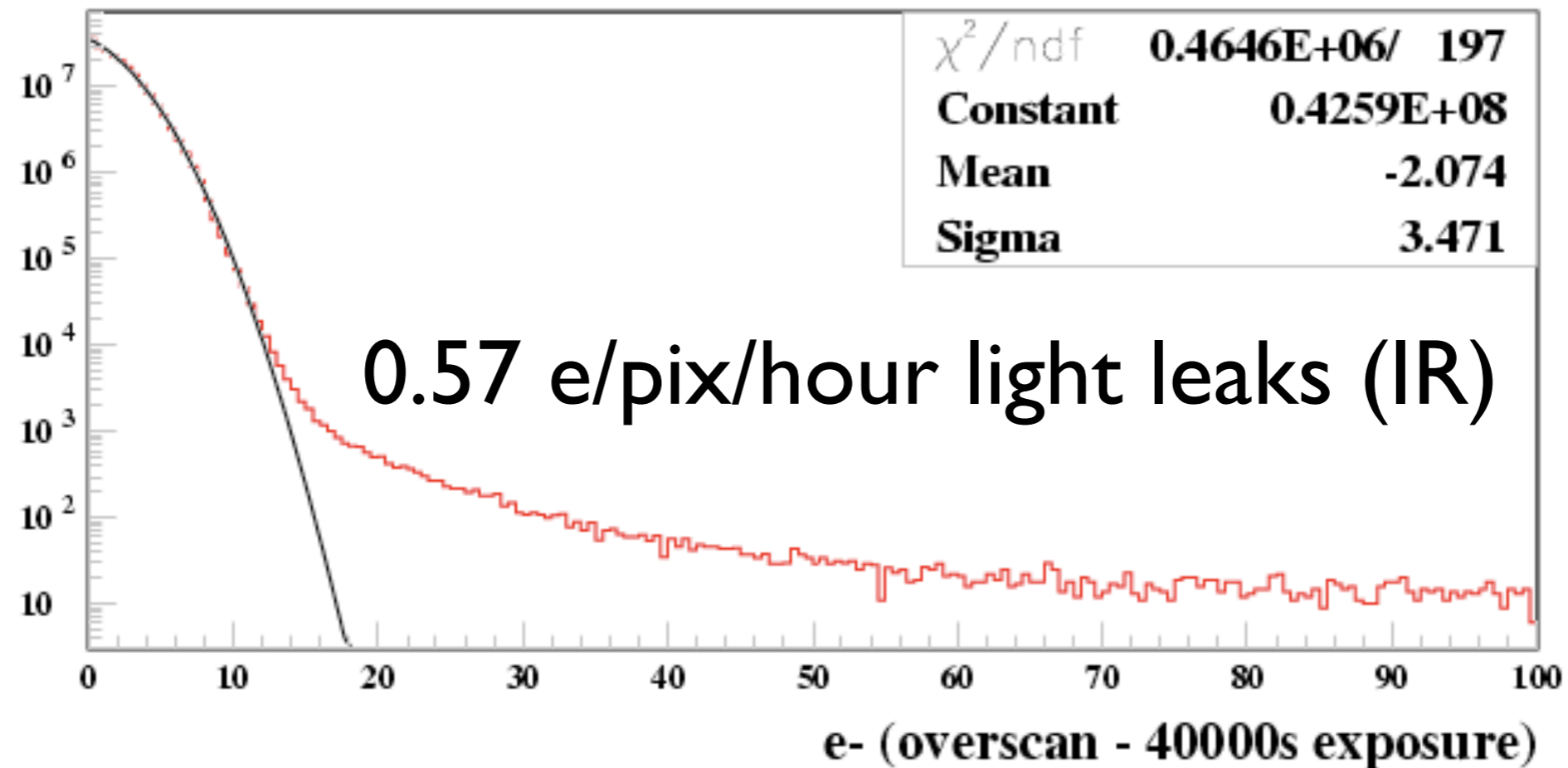
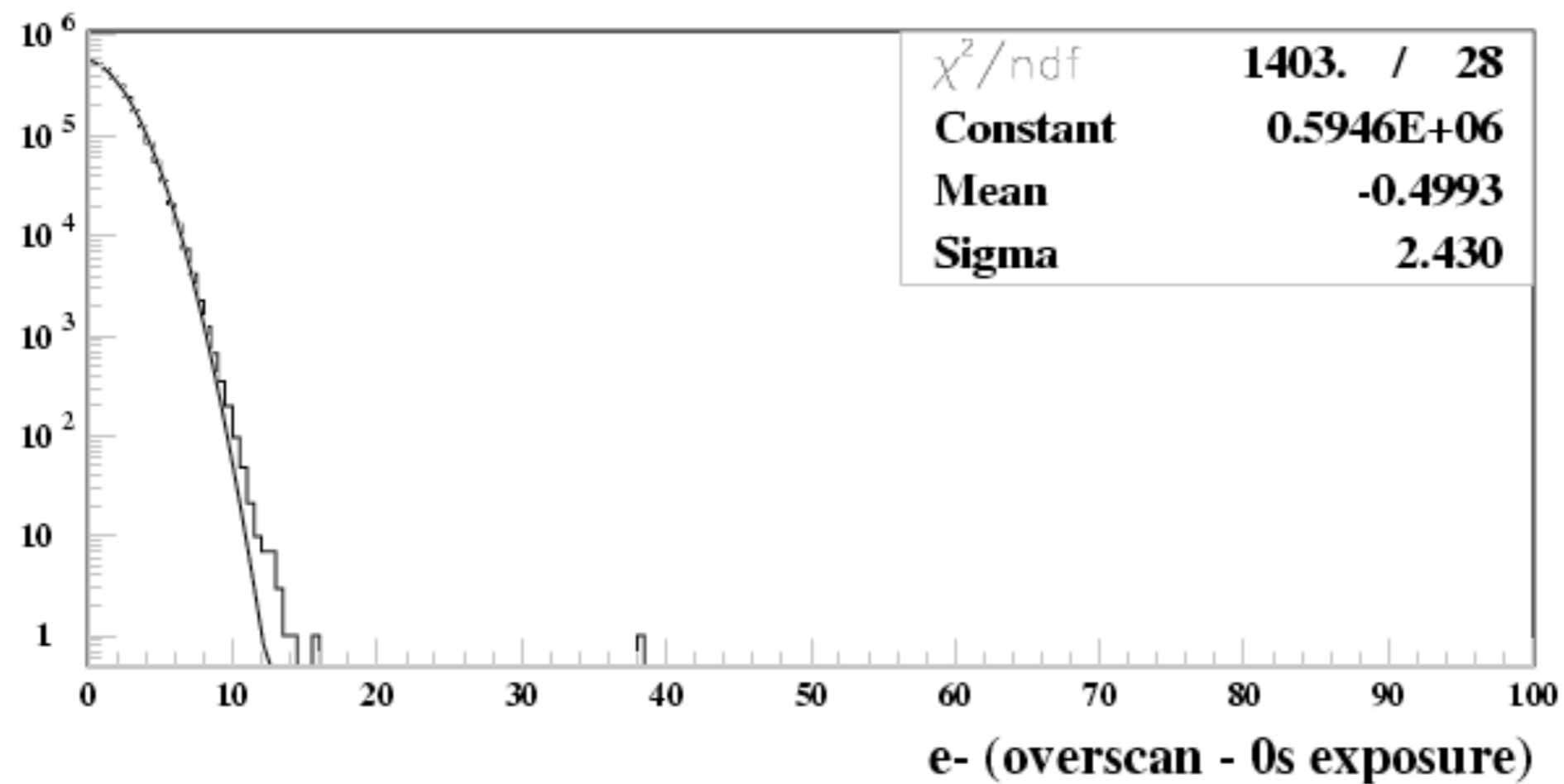
New wide field imager (3 sq-deg) for the Blanco 4m telescope to be delivered in 2010 in exchange for 30% of the telescope time during 5 years. Being built at FNAL.

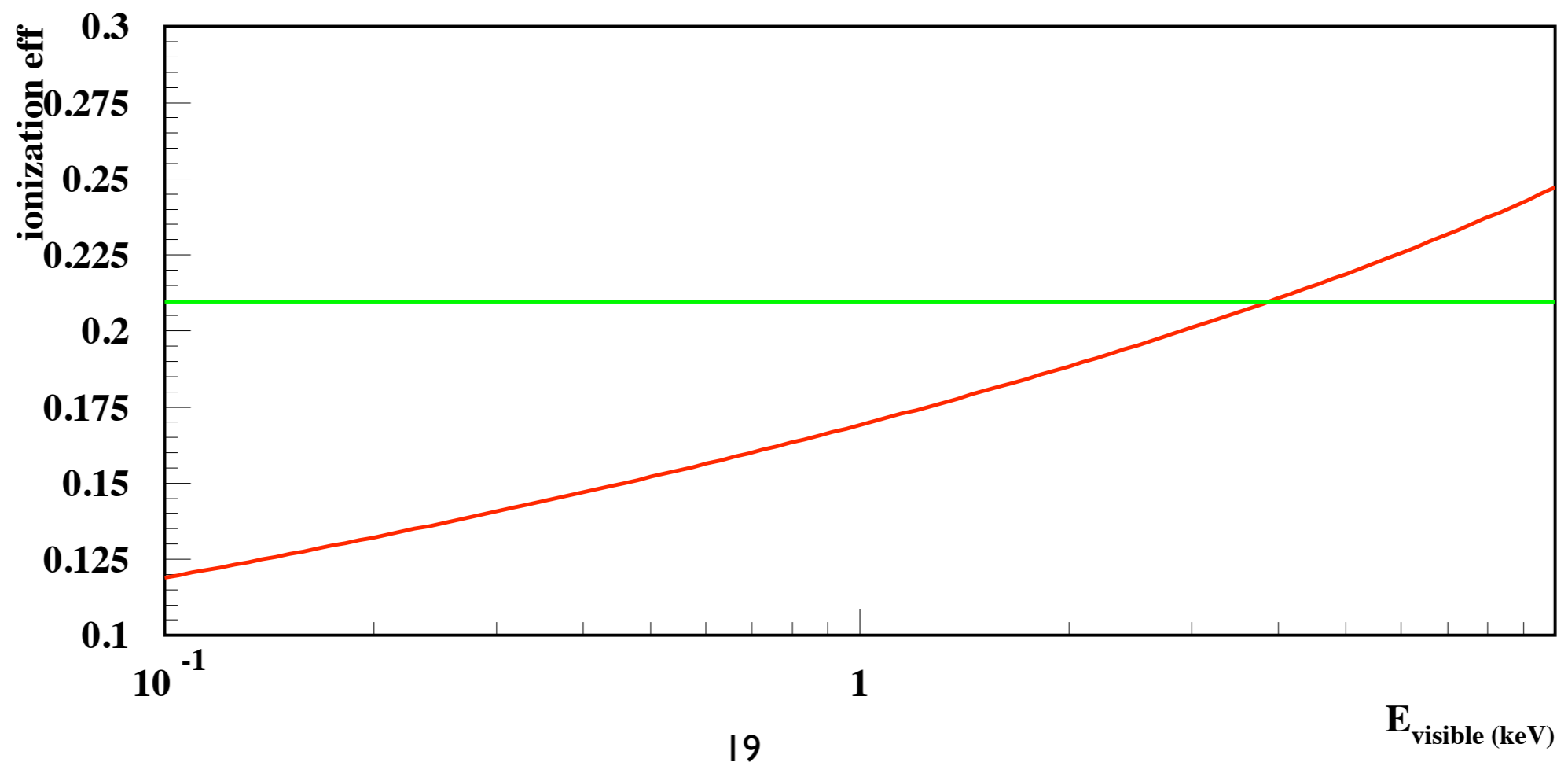
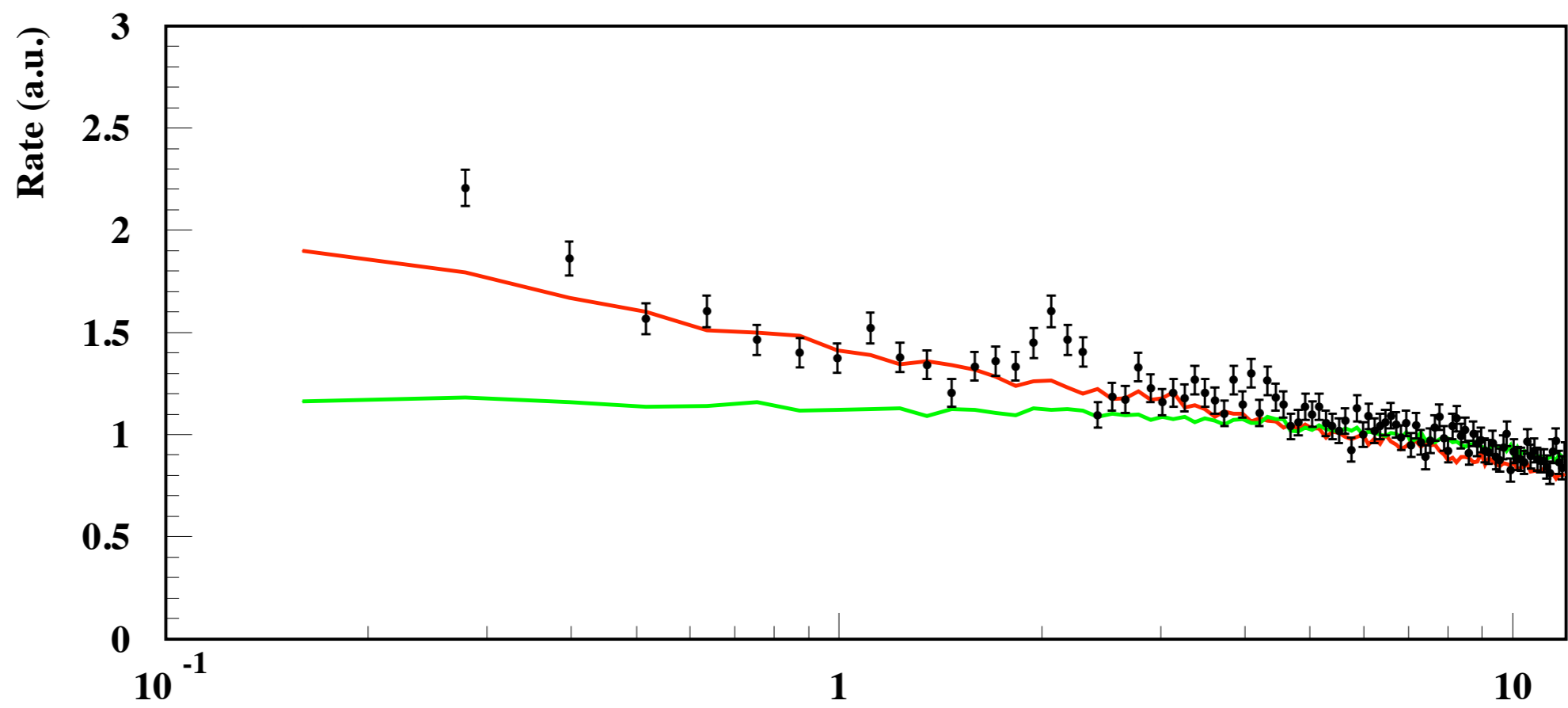


low noise readout for ^{55}Fe X-rays

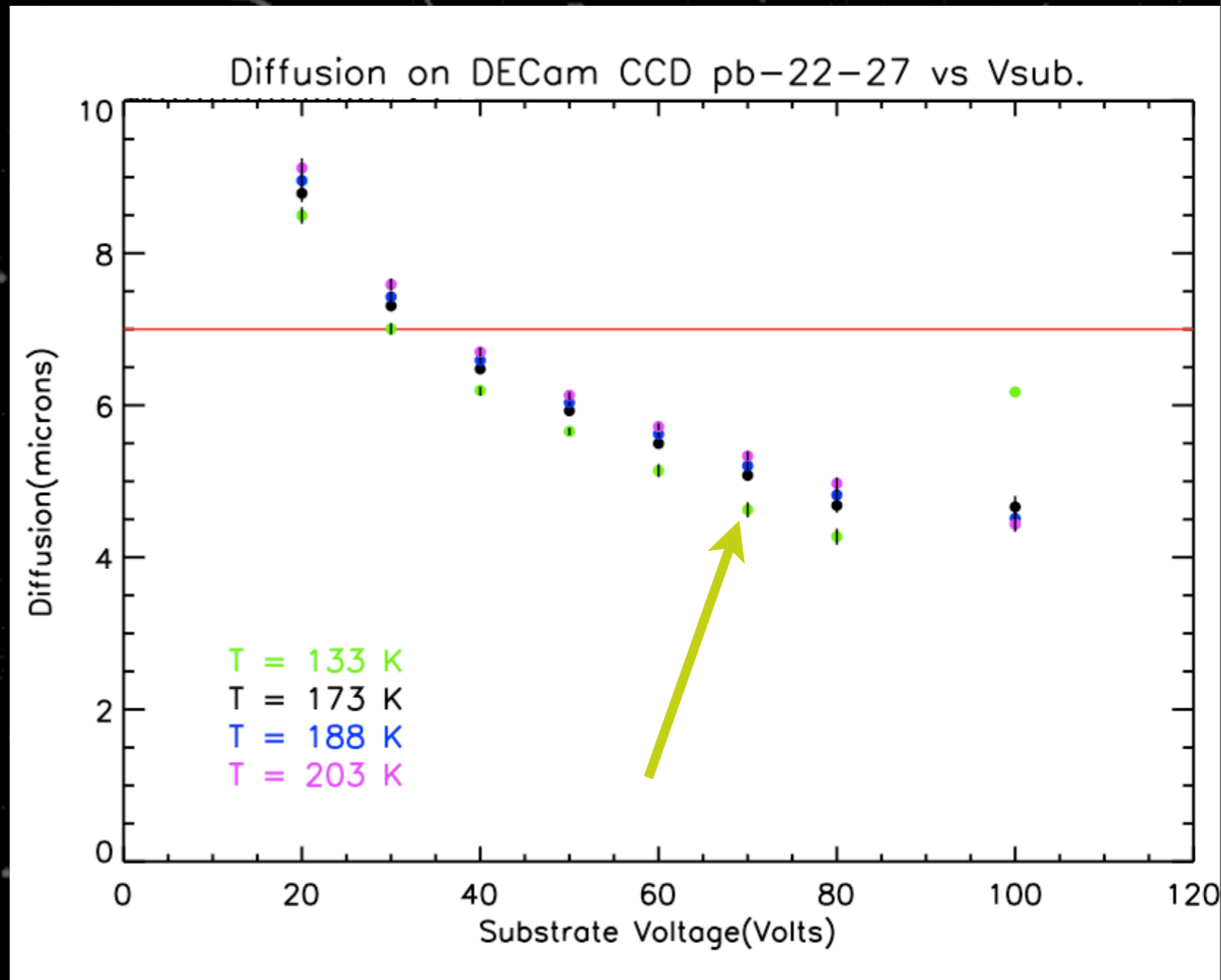
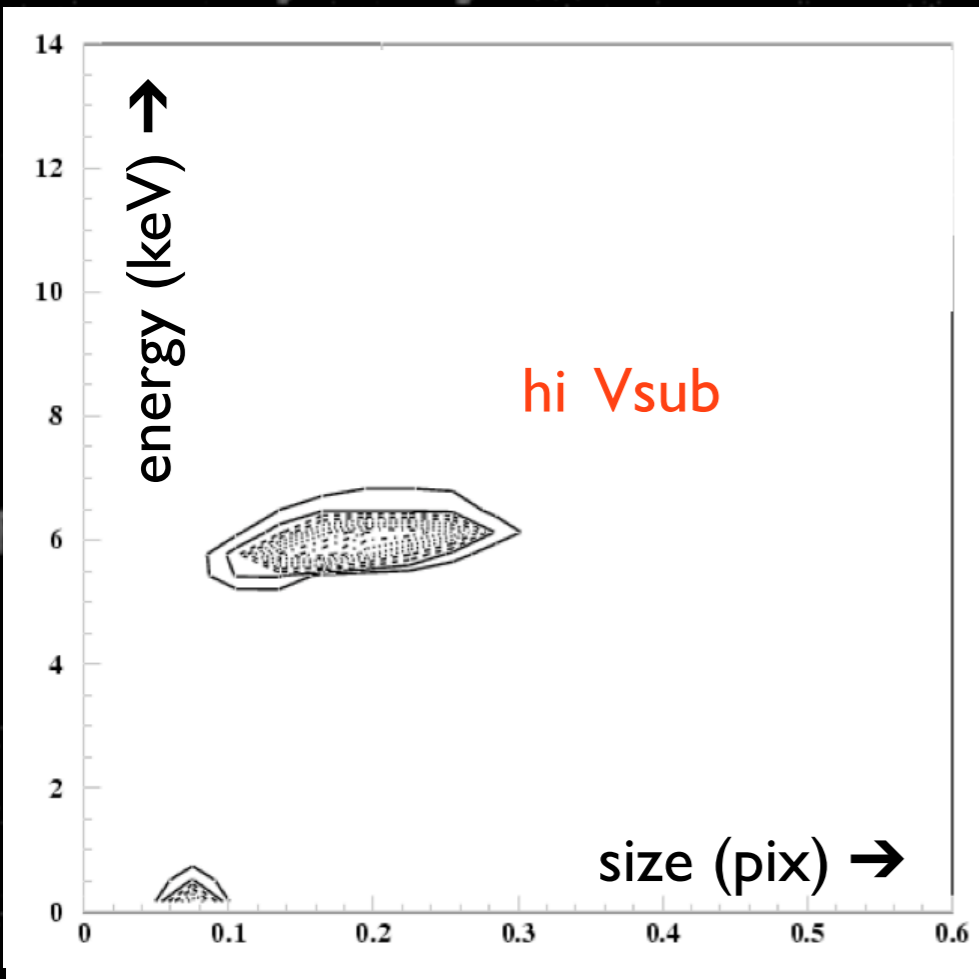


fano factor:
 $F = (18^2 - 2^2) / 1620.$
 $F = 0.17$
typical for CCDs, in
silicon: 0.10



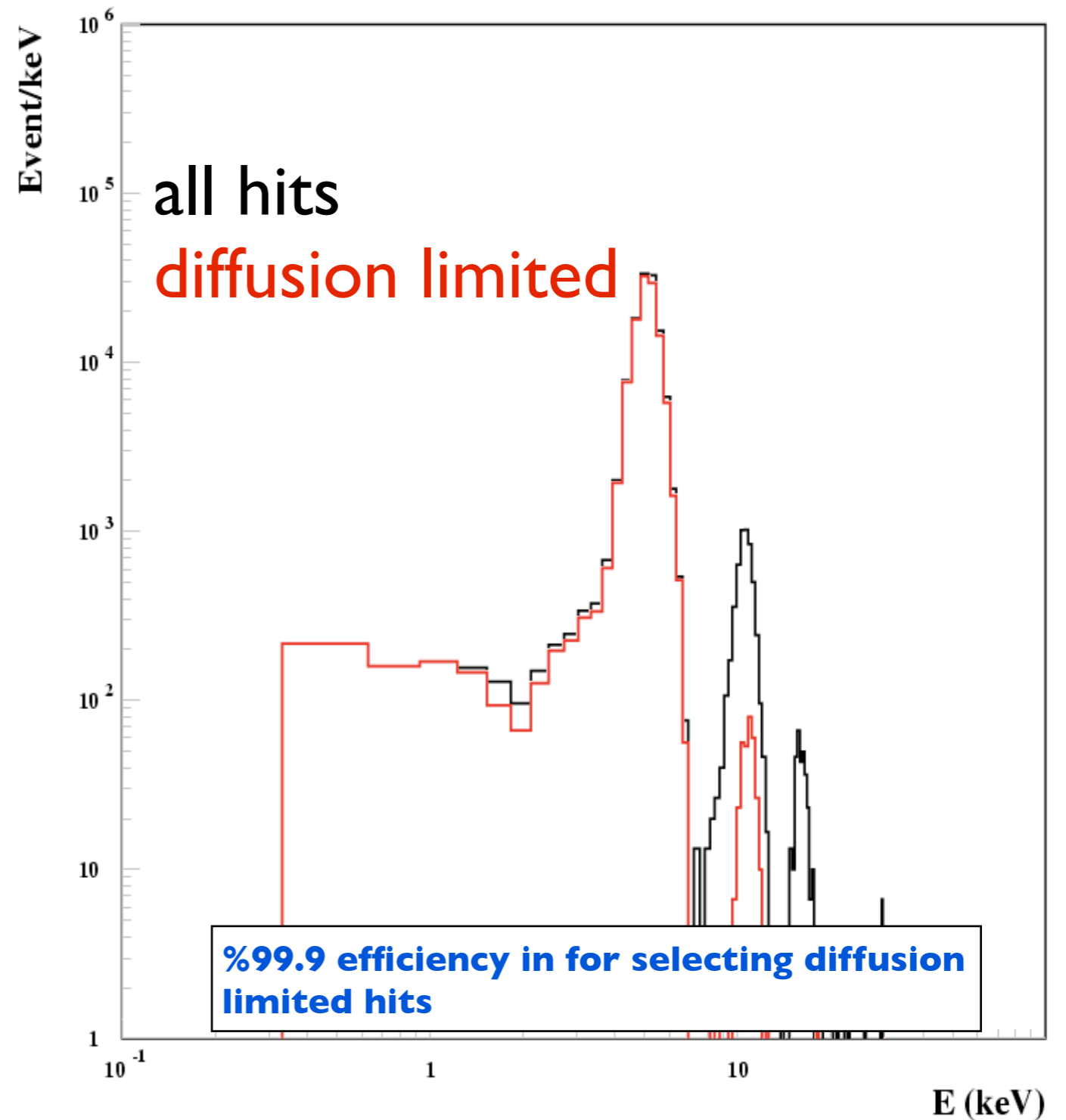


Charge diffusion with X-rays

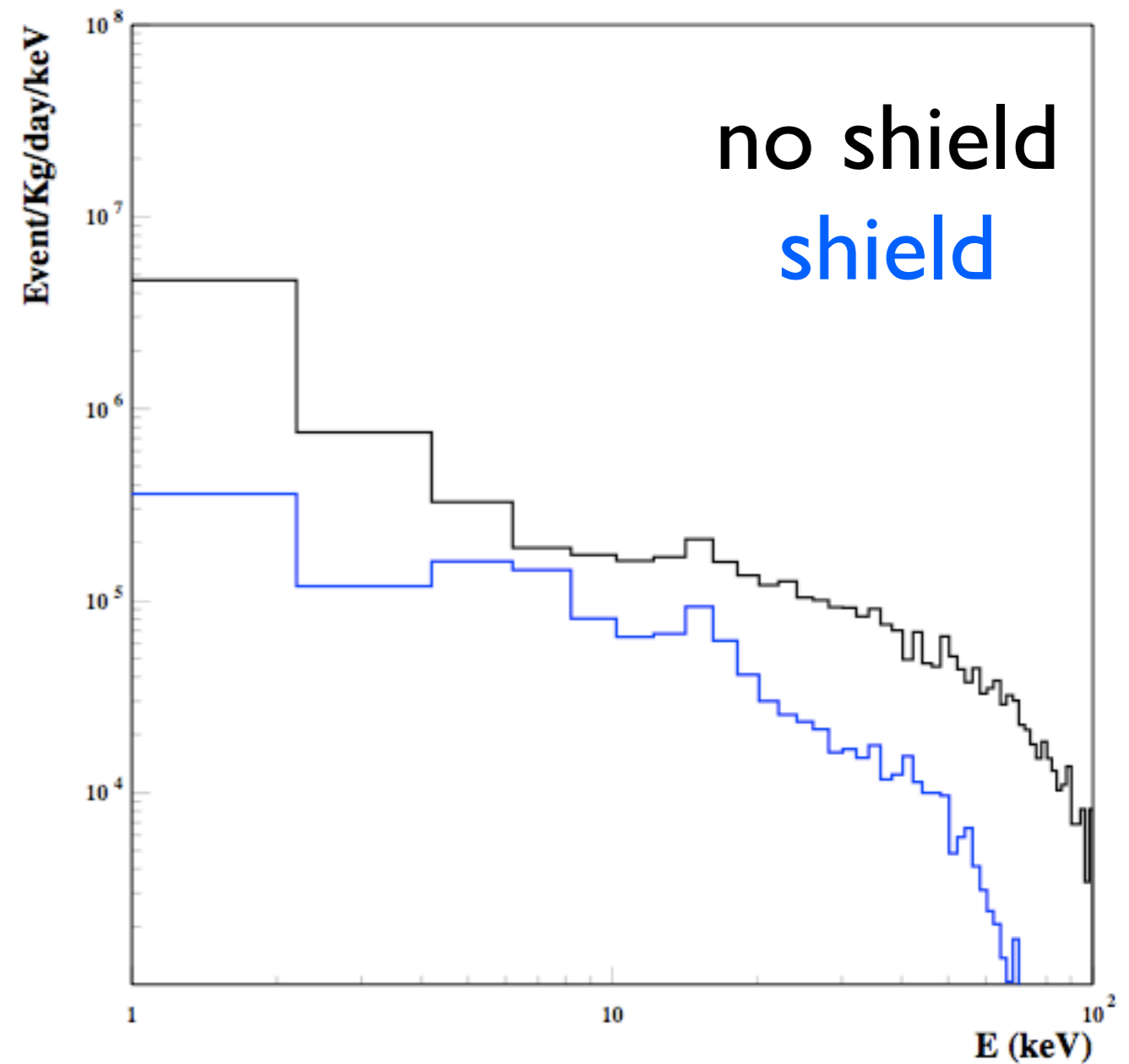
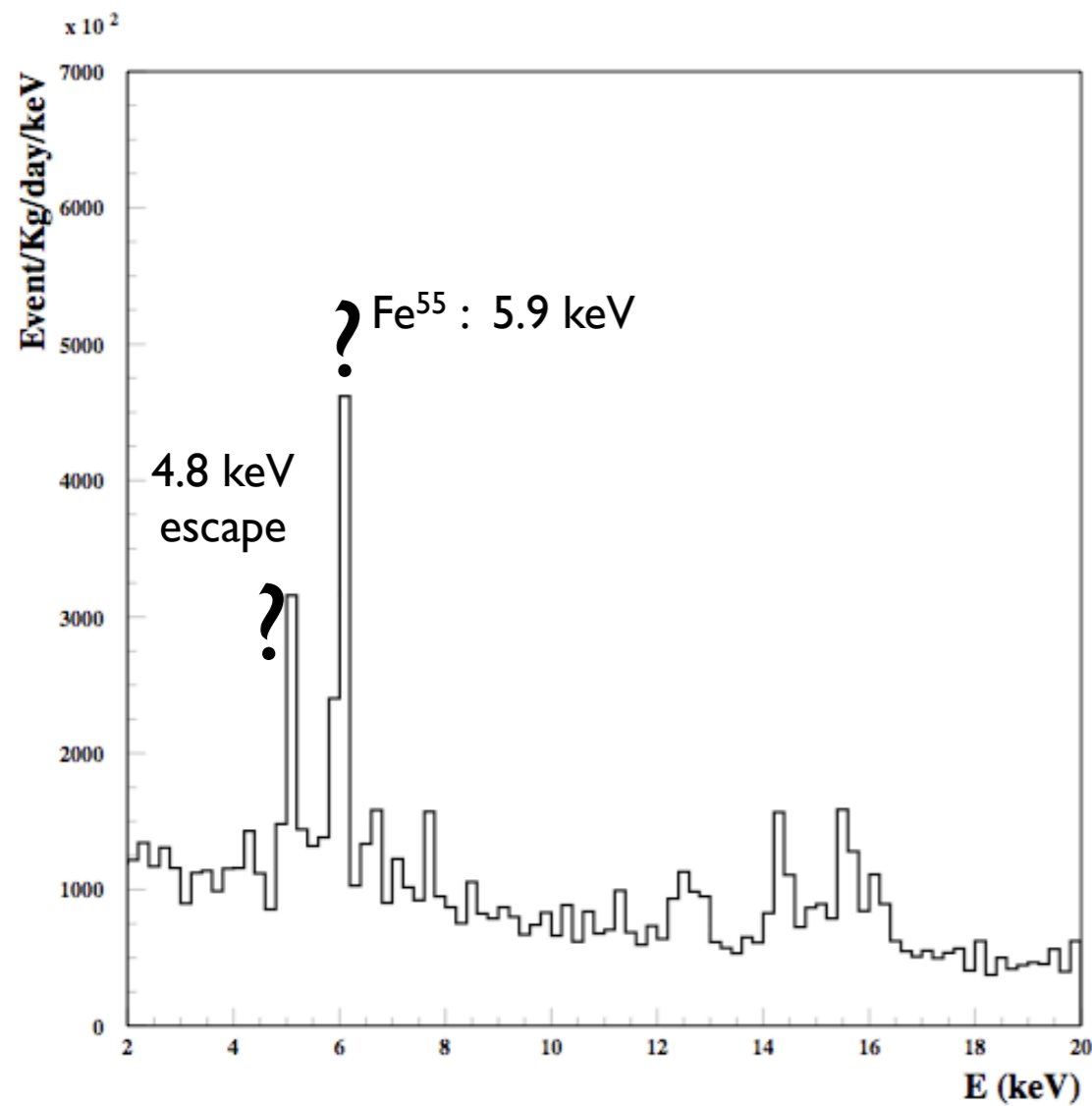


X-ray ^{55}Fe (5.9 keV)

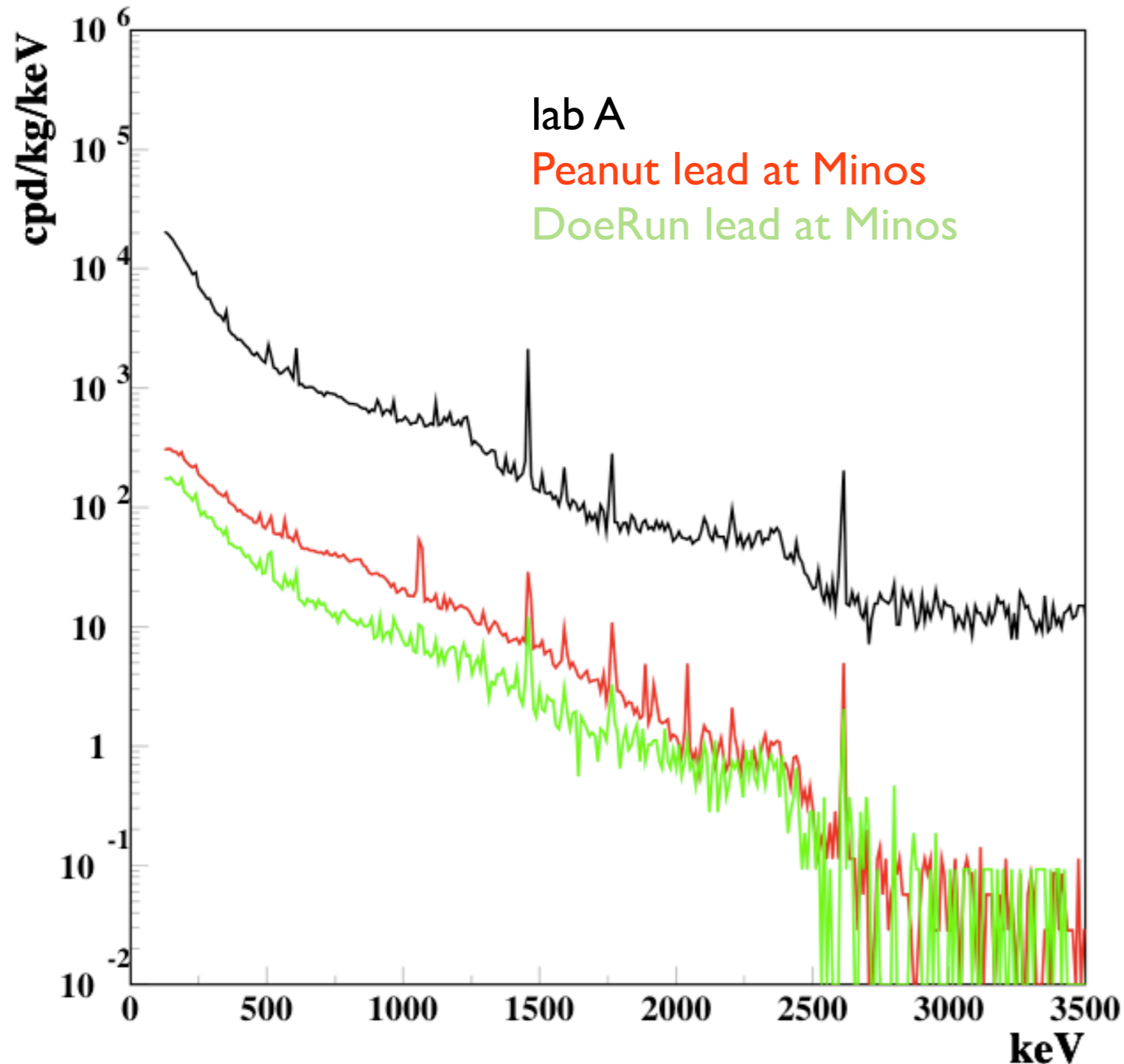
point like hits
(diffusion limited)



runs at Lab-A gave 10^6 cpd/keV... too high!



Shield studies:Ge detector at Minos

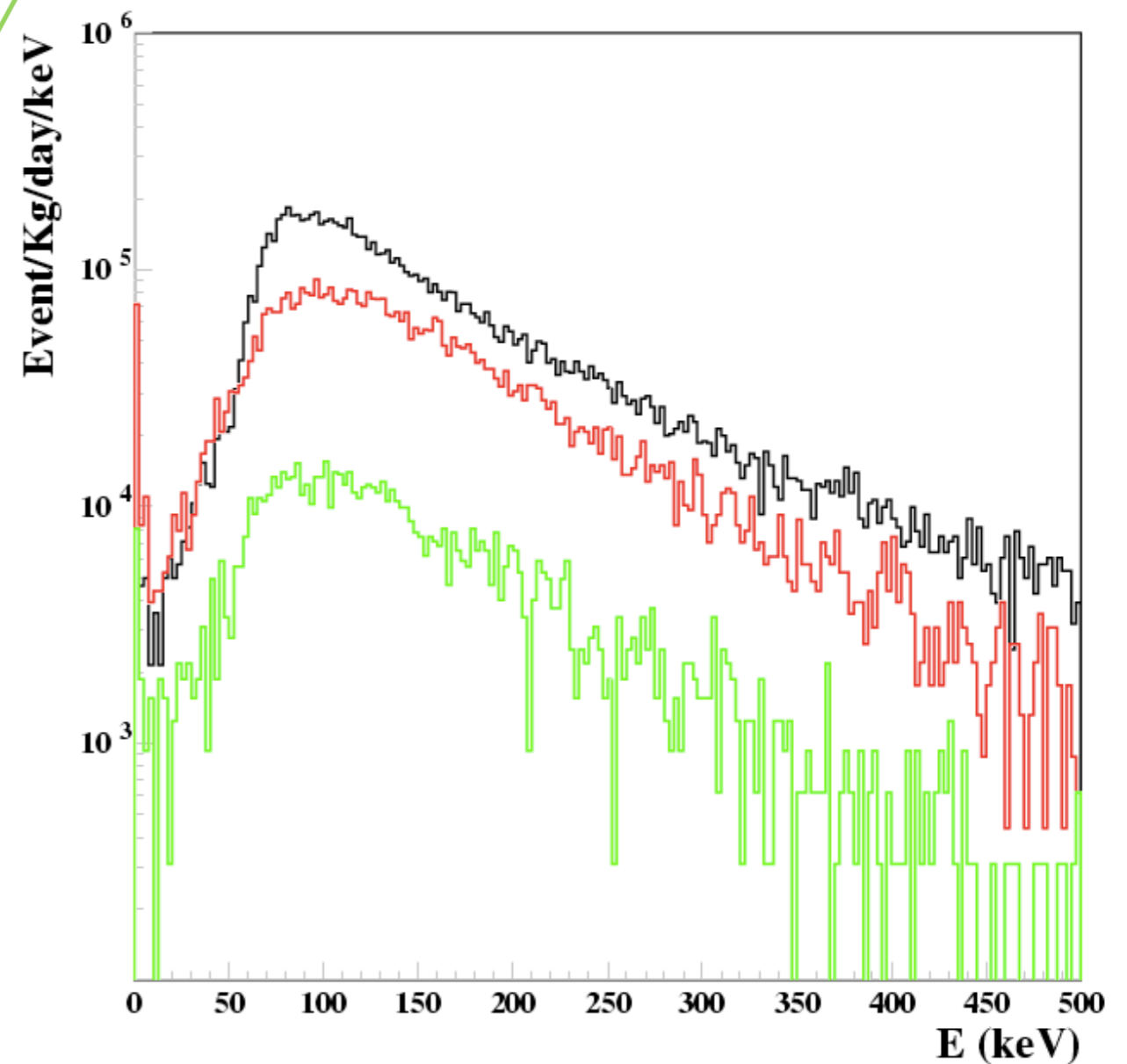
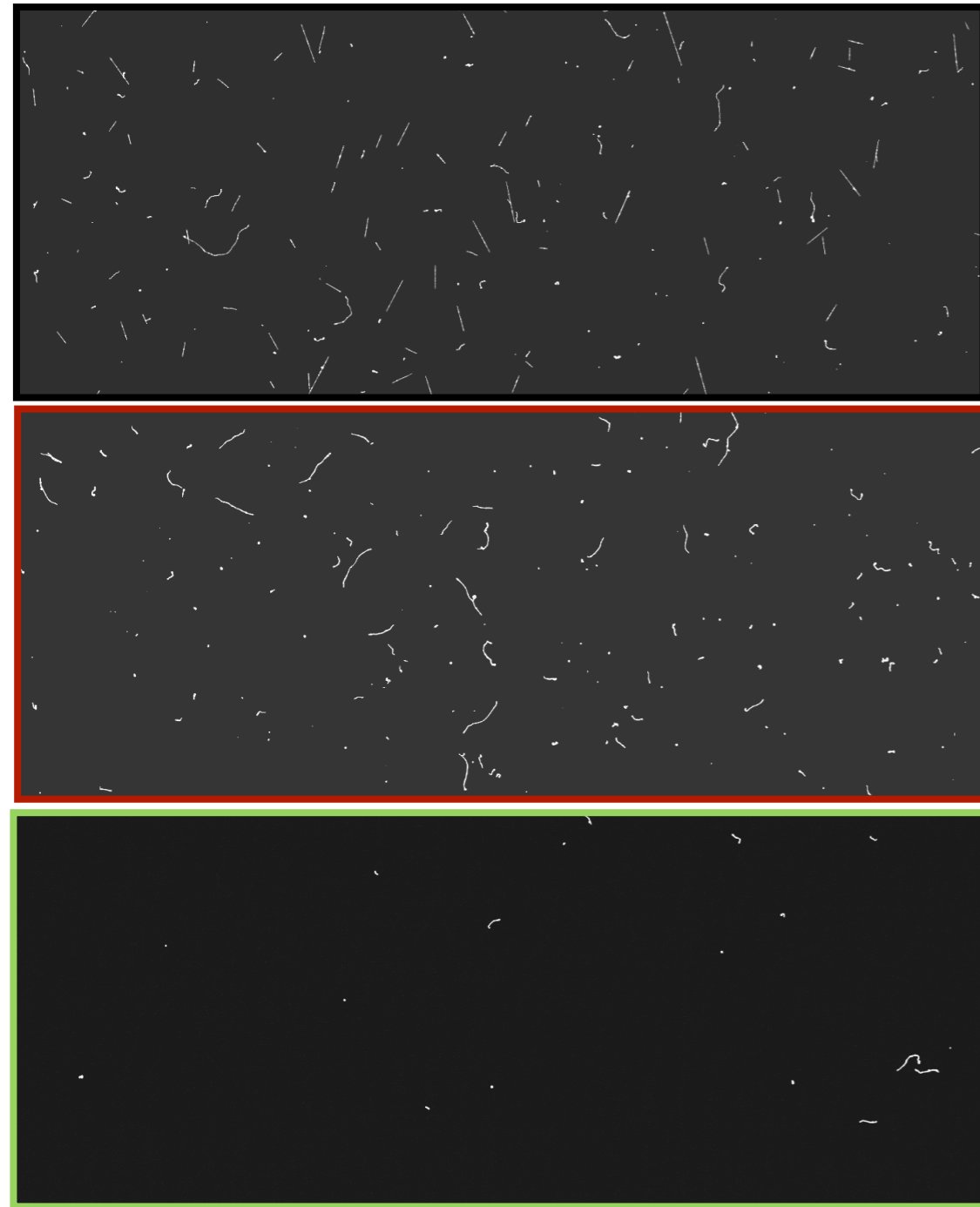


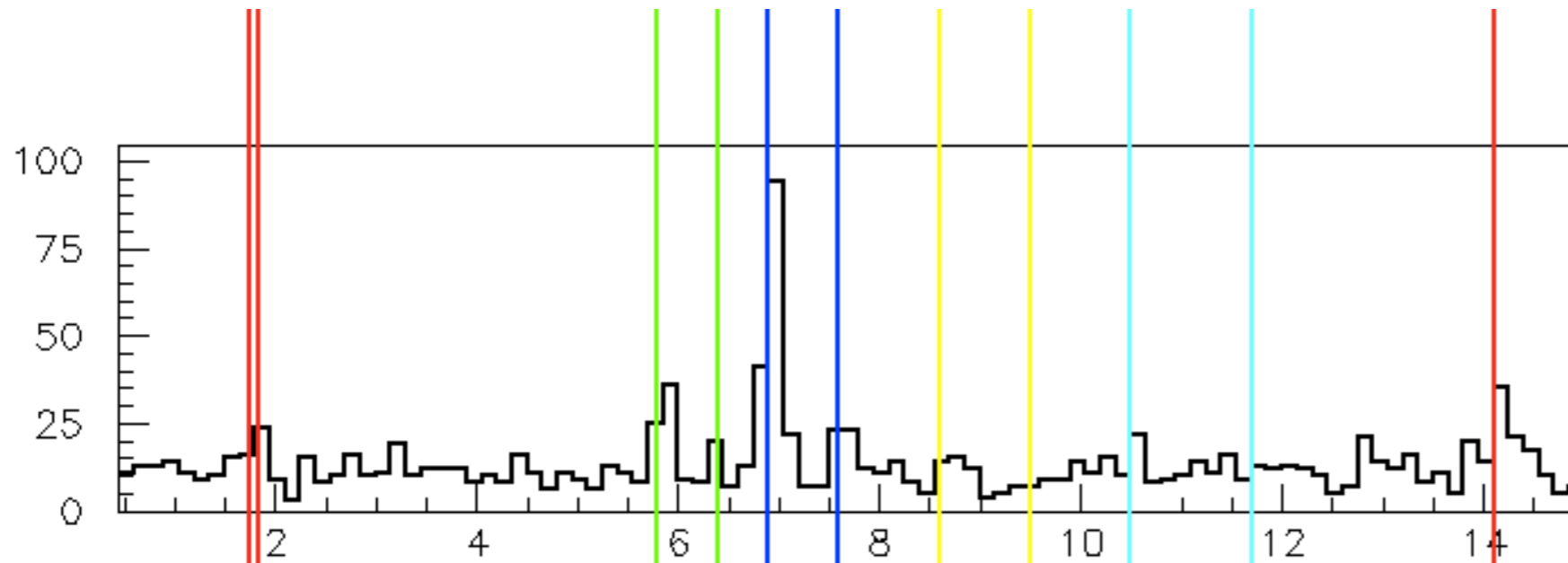
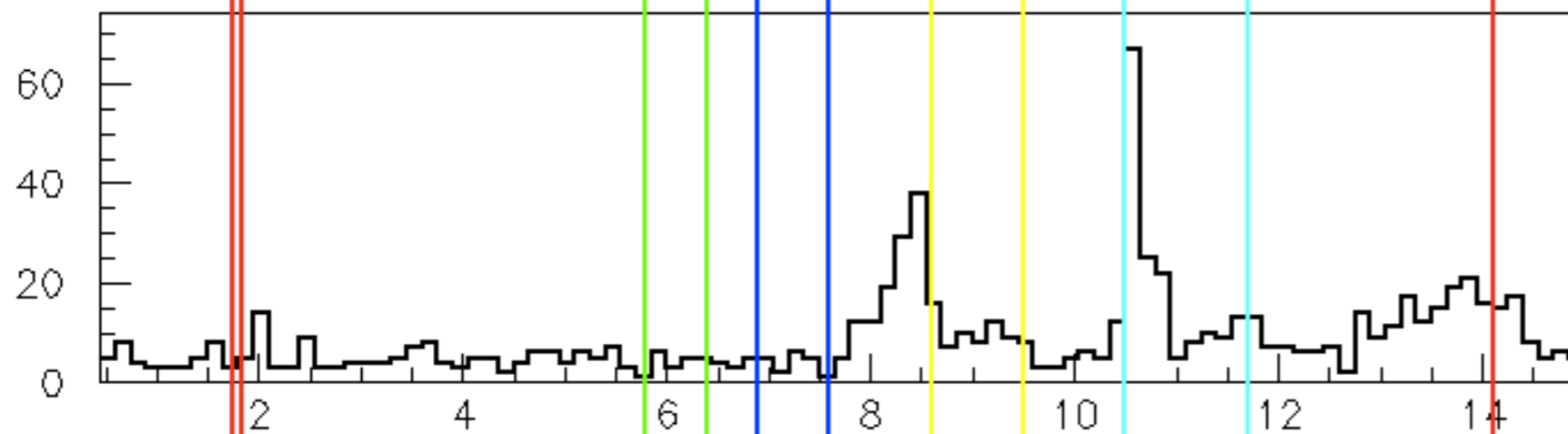
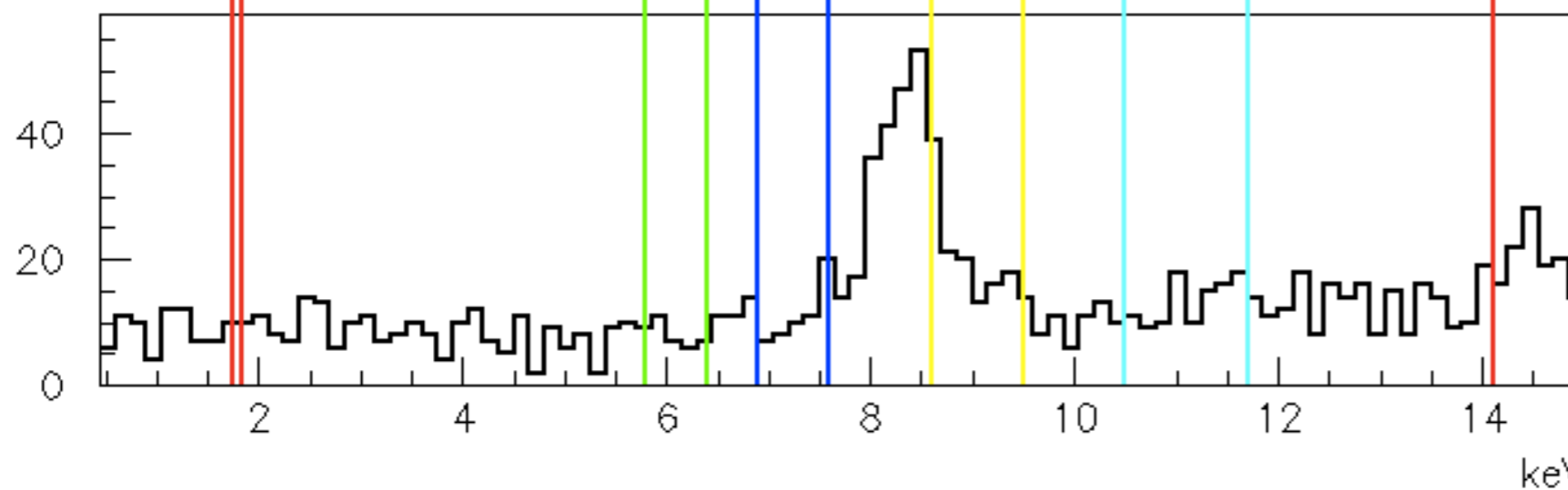
Purchased new lead before the price went down... and made a shield at Minos for the Ge detector.

Test indicated we could get about 2 orders of magnitudes.

tracks:

- Lab-A
- Minos
- Minos + lead shield



A**B****C**

Each detector in our setup sees a different spectrum.

X rays:

Si (Silicon)

Mn (Manganese)

Co (Cobalt)

Zn (Zinc)

As (Arsenic)

Sr (Strontium)